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DRAFT

Work Plan for an Engineering Evaluation/Cost Analysis in Support of the Intrinsic Remediation (Natural Attenuation) Option at the Former AGE Fuel Facility (Building 4715)

Seymour Johnson Air Force Base
Goldsboro, North Carolina

Prepared For

Air Force Center of Environmental Excellence
Brooks Air Force Base
San Antonio, Texas

and

Seymour Johnson Air Force Base
Goldsboro, North Carolina

March 1995

AQ M01-03-0490

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WORK PLAN FOR AN ENGINEERING EVALUATION/COST ANALYSIS IN SUPPORT OF THE INTRINSIC REMEDIATION (NATURAL ATTENUATION) OPTION AT THE FORMER AEROSPACE GROUND EQUIPMENT FUEL FACILITY SEYMOUR JOHNSON AIR FORCE BASE GOLDSBORO, NORTH CAROLINA

March 1995

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

SEYMOUR JOHNSON AIR FORCE BASE
GOLDSBORO, NORTH CAROLINA

Prepared by:

Parsons Engineering Science, Inc.
401 Harrison Oaks Blvd., Suite 210
Cary, North Carolina 27513

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of groundwater contaminated with petroleum products at the former Aerospace Ground Equipment (AGE) fueling facility adjacent to Building 4715 located at Seymour Johnson Air Force Base (AFB), Goldsboro, NC. This EE/CA will provide the framework for the site's Corrective Action Plan under the North Carolina requirements. Several remedial options will be evaluated during the EE/CA possibly including free product removal; groundwater extraction, treatment, and reinjection (i.e., pump and treat); air sparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. All hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options will be collected under this program. However, this work plan is oriented toward the collection of hydrogeologic data to be used in support of intrinsic remediation for restoration of fuel-hydrocarbon-contaminated groundwater. When applicable, site-specific information may be obtained from previous studies conducted at Seymour Johnson AFB.

Data collected during the field effort will also be used as input to the Bioplume II model code. As part of the EE/CA, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The Bioplume II modeling effort for this site involves completion of several tasks which are described in the following sections of this work plan.

This work plan was based on the statement of work (SOW) for this project, site-specific data from existing characterization reports, and discussions among representatives from U.S. Air Force Center for Environmental Excellence (AFCEE), Seymour Johnson AFB. The North Carolina Division of Environmental Management Washington Regional Office (DEM), and Parsons ES at a meeting at Seymour Johnson

AFB on January 10, 1995. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and Seymour Johnson AFB.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide an EE/CA for remediation of groundwater contamination at the AGE site located at Seymour Johnson AFB. However, this project is part of a larger, broad-based initiative being conducted by AFCEE, in conjunction with the U.S. Environmental Protection Agency (EPA) and Parsons ES, to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in groundwater, and to model this degradation using the Bioplume II numerical groundwater model. For this reason, the activities described in this work plan are directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, will also be collected under this program. This work plan describes the site characterization activities which will be performed in support of the EE/CA and the Bioplume II modeling effort.

Proposed site characterization activities include Geoprobe® testing, monitoring point placement, soil and groundwater sampling, and aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated to historical site data. Upon completion of the Bioplume II model, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate groundwater remedial technology based on available data.

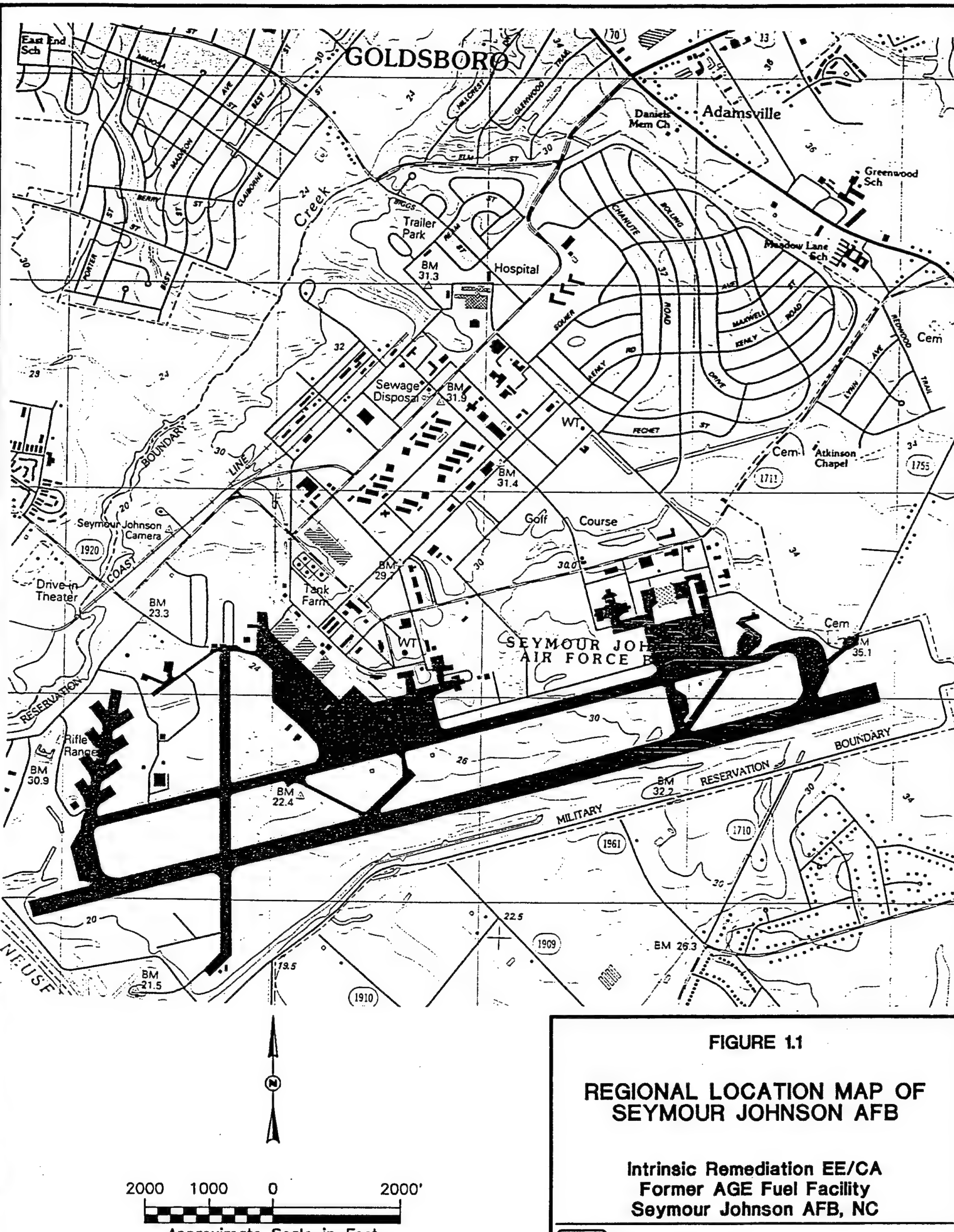
This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and EE/CA report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. Appendix A contains a listing of the containers, preservatives, packaging, and shipping requirements for groundwater samples.

1.2 SITE BACKGROUND

Seymour Johnson AFB is located near the city of Goldsboro approximately 50 miles southeast of Raleigh, North Carolina. The base is bounded on the southwest by the Neuse River, and on the northwest by Stoney Creek. Figure 1.1 is a regional location map showing the position of Seymour Johnson AFB relative to the surrounding area. Seymour Johnson AFB contains approximately 3,216 acres of land on the main base area.

Seymour Johnson AFB was established in 1942 as a technical school and training facility. At the end of World War II, the base became an Army Air Force Separation Center, and in 1946 was deactivated. In 1949, the property was deeded to the city of Goldsboro. Piedmont Airlines used the air field for regular commercial flights from 1950 to 1953. During this time, other base facilities were leased to private industry for warehousing, light manufacturing, and housing. In 1952, the city of Goldsboro returned the property to the Federal Government, and in 1956 the base was reopened as a Tactical Air Command Base. The base now primarily serves as the home of the Air Combat Command's 4th Fighter Wing.

The former AGE fueling facility is located in the central portion of the base, along Martin Street and adjacent to Building 4715 (Figures 1.2 and 1.3). The facility served as a fueling station for generators, tow trucks, and other support vehicles and equipment. The facility was taken out of service for fueling operations in 1994, when the site's USTs were taken out of service. The facility utilized several underground storage tanks (USTs) for the storage of various fuels. One 2,000 gallon JP-4 UST, one 2,000 gallon gasoline UST, and one 2,000 gallon diesel fuel UST were located at the



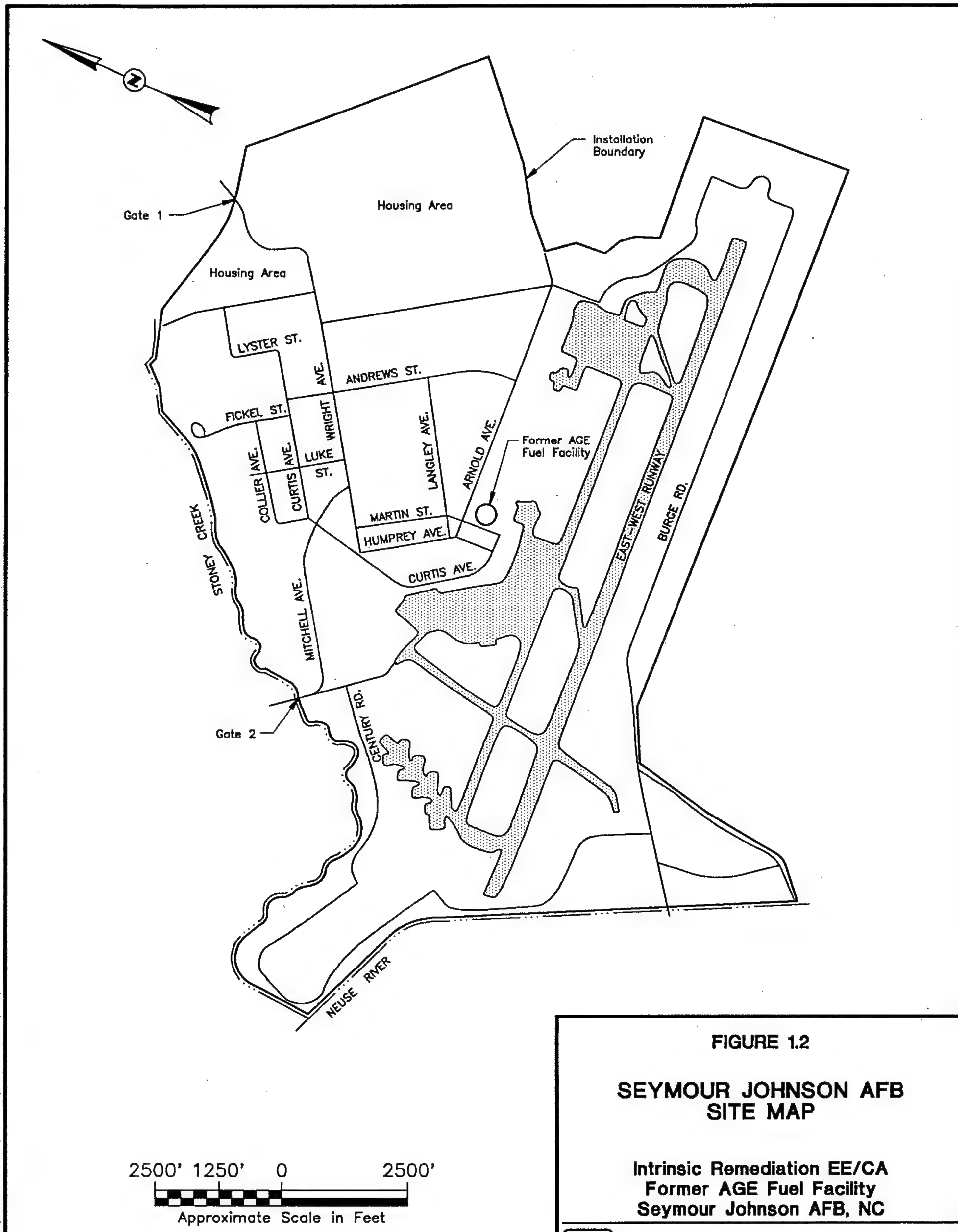
Source: USGS, 1982

FIGURE 1.1

REGIONAL LOCATION MAP OF SEYMOUR JOHNSON AFB

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina



Source: Law Environmental, 1992, and Seymour Johnson AFB.

FIGURE 1.2

SEYMOUR JOHNSON AFB SITE MAP

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

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Cary, North Carolina

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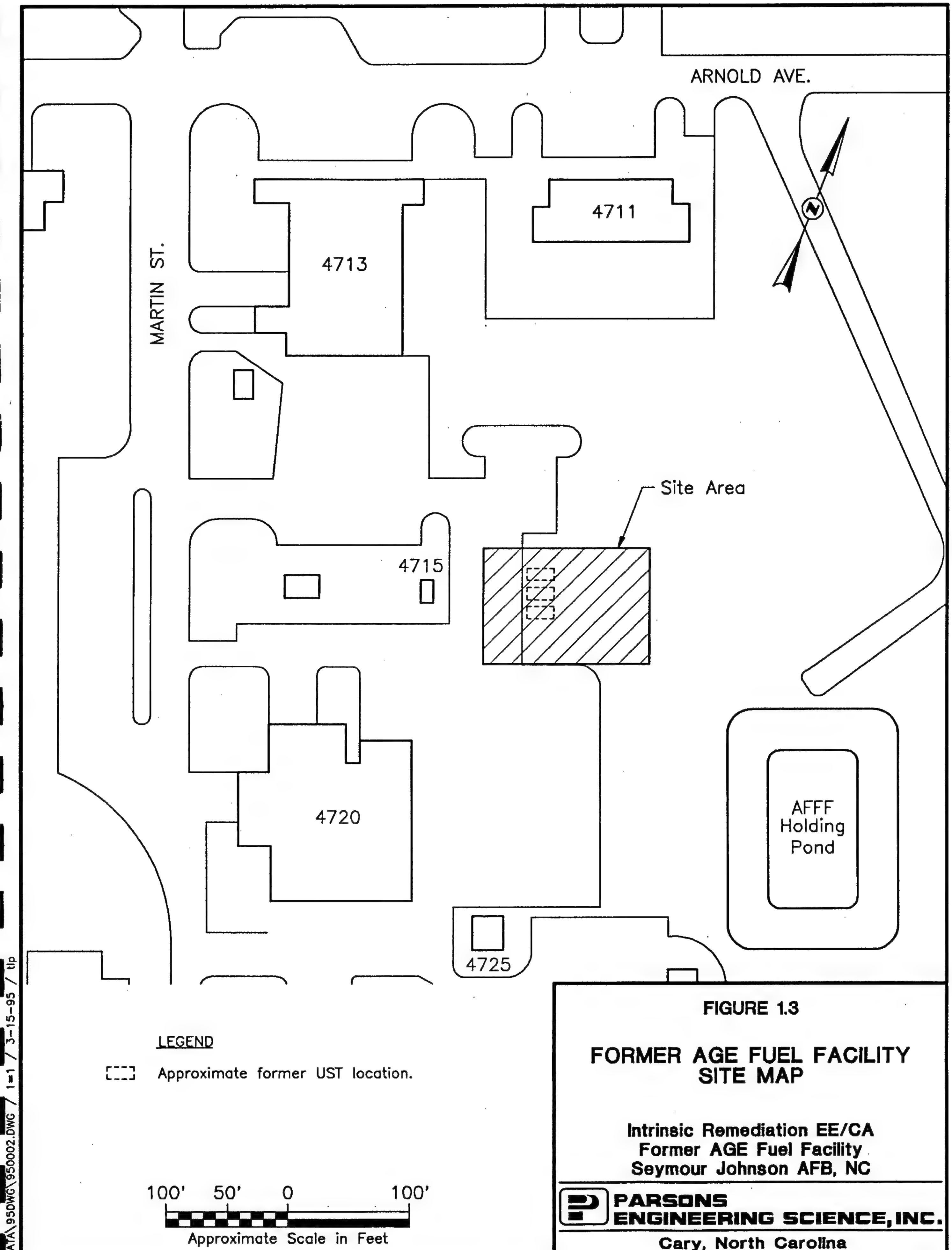

FIGURE 1.3

FORMER AGE FUEL FACILITY
SITE MAP

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

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facility. The USTs were removed and closed in 1994. The approximate locations of all the tanks formerly utilized on-site are shown in Figure 1.3.

Between January 19 and 25, 1995, Parsons ES and the US Army Corps of Engineers (USACE) performed a preliminary screening of the subsurface conditions at the former AGE fueling facility. The USACE Site Characterization and Analysis Penetrometer System (SCAPS) truck was employed to perform cone penetrometry, laser induced fluorescence, soil sampling, and installation of direct push monitoring points. This preliminary screening provided data regarding the extent of petroleum contamination in the subsurface, as well as lithologic information.

Site investigations have been performed on numerous other locations at the base. In addition to the data collected during the preliminary subsurface screening, reports of investigations under the Air Force Installation Restoration Program (IRP) were reviewed to formulate the conceptual model presented in Section 2.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing data from sites at Seymour Johnson AFB were reviewed in addition to the data collected using the SCAPS truck. All the data were used to develop a conceptual model of the groundwater flow and contaminant transport system at the former AGE fueling facility. This conceptual model will guide the collection of additional data which will be used to support the Bioplume II modeling effort, and to evaluate potential remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site data. Section 2.2 presents the preliminary conceptual groundwater flow and solute transport model which was developed based on these data.

2.1 DATA REVIEW

The Remedial Investigation Report prepared by Law Environmental, Inc. (1992) contains current environmental and regional data for the site. This and other reports and current CAD site maps provided by Seymour Johnson AFB were reviewed. Information was provided by Seymour Johnson regarding the observations made during the UST closure. Preliminary site screening was performed by Parsons ES and USACE as described in Section 2.1.3. Relevant data are summarized in the following sections.

2.1.1 Climate, Topography, and Surface Hydrology

The Goldsboro, NC area has a temperate climate resulting from its latitude and its close geographic proximity to the Atlantic Ocean. Spring and fall are characterized by a succession of warm and cold periods associated with storm activity. Summers and winters are characterized as humid, making the winters more penetrating and the summers more sweltering than experienced in the drier climates of the central United States (Climates of the States, 1985). The mean annual precipitation for the base is approximately 50 inches per year (NCSU, 1988). Mean daily temperatures range from 41.5 to 79.7 degrees Fahrenheit (^{o}F) (NCSU, 1988).

Seymour Johnson AFB exhibits little topographic variation. The base is nearly level, with steeper drops towards the floodplains of the Neuse River and its tributary, Stoney Creek. The former AGE fueling area is located at approximately 90 feet (ft)

above mean sea level (msl). Any significant elevation changes at Seymour Johnson AFB and surrounding areas are mostly the result of erosional activity and/or stream channel development.

The primary surface water drainage feature at Seymour Johnson AFB is the Neuse River, which forms the southwestern border of the base. Stoney Creek, a major tributary to the Neuse River, forms the northwestern base boundary. Storm water is drained from the base to either Stoney Creek or the Neuse River through a system of drainageways and subsurface piping. Many of the drainageways are in direct communication with groundwater in the surficial aquifer and act as groundwater discharge boundaries.

2.1.2 Site Geology and Hydrogeology

Seymour Johnson AFB is located in the middle region of the Atlantic Coastal Plain Physiographic Province, a wide wedge-shaped belt of Cretaceous to Recent sedimentary deposits (Foster, 1950). The western boundary of the middle Coastal Plain is formed by the Coats scarp at an elevation of 275 feet above mean sea level (msl). In the middle Coastal Plain, land slopes gently to the east to the Surry scarp (at 94 feet msl) where the lower region of the Coastal Plain begins. Seymour Johnson AFB is located approximately 25 miles east of the Fall Line, which marks the boundary between the Coastal Plain and the Piedmont physiographic provinces. In the area of the base, the geology consists of unconsolidated sediments unconformably overlying pre-Cretaceous bedrock (RTI, 1988). The Coastal Plain sediments are primarily Quaternary and Tertiary deposits overlying about 130 feet of Cretaceous marine sediments.

Beneath a thin surficial veneer of Quaternary and Tertiary sediments, the Black Creek Formation and the Cape Fear Formation underlie the area around Seymour Johnson AFB. At the base, the surficial deposits consist of the Goldsboro Sand and the Sunderland Formation. The Holocene Goldsboro Sand is made up of a fairly uniform medium-grained sand with some sandy clay and clay lenses. The Pliocene Sunderland Formation consists of poorly sorted sediments ranging from sandy clay and clay to gravel deposits. The Black Creek Formation is made up of dark gray to black, thinly laminated montmorillonite clays interbedded with glauconitic sand lenses. At the base, the Black Creek Formation is greater than 50 feet thick. The Cape Fear Formation consists of light-colored, poorly sorted quartz sands and montmorillonitic feldspathic

clays. The formation contains mica, lignite, and iron sulfides that are found as concretions, disseminated grains, or as a replacement mineral in wood fragments.

The uppermost hydrogeologic unit at Seymour Johnson AFB consists of an unconfined aquifer within the surficial deposits. Groundwater flow directions within the surficial unconfined aquifer are controlled by topography on a local scale. The overall direction of flow in the surficial aquifer is generally to the west and northwest toward the Neuse River and Stoney Creek. Groundwater at the former AGE fuel facility site is found at a depth of approximately 12 to 14 ft below land surface (bls).

The surficial unconfined aquifer is underlain by a series of interbedded sands and clays making up the regional, confined aquifer units of the Black Creek aquifer. At Seymour Johnson AFB, the productive zones of the Black Creek aquifer are found below 10 feet msl (Law Environmental, 1992). Beneath the Black Creek aquifer, the Cape Fear Formation contains the third major aquifer system in the area. Many production wells tap both the Black Creek and the Cape Fear aquifers. Figure 2.1 shows a general hydrogeologic section for the Seymour Johnson AFB area.

Groundwater depths within the surficial aquifer range from approximately 1 foot bls near the Neuse River and tributaries to about 15 feet bls in the central portion of Seymour Johnson AFB. Based on data obtained from four monitoring points installed during the preliminary site screening, the site may lie along a groundwater divide (see Figure 2.2). The directions of groundwater flow at the former AGE fuel facility site appears to be to the northwest and southeast. The hydraulic conductivity of the surficial aquifer at Seymour Johnson AFB has been reported to range from 0.1 to 8.6 feet per day (ft/day). The hydraulic conductivity of the Black Creek aquifer at Seymour Johnson AFB has been reported to be approximately 1.45 ft/day (Law Environmental, 1992).

2.1.3 Cone Penetrometry

Subsurface conditions at the former AGE fuel facility site have been initially characterized with CPT coupled with LIF. Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring the resistance of different soil types against the conical probe of the penetrometer as it is pushed into the subsurface. The resistance on the pressure tip and friction sleeves on the side of the cone are then correlated to soil core data to calibrate the CPT readings to the lithologies

HYDROGEOLOGIC UNIT	GEOLOGIC FORMATION	THICKNESS (FEET)	DESCRIPTION
Surficial Aquifer	Goldsboro Sand	0 – 20	Medium–grained sand with some clay and/or sandy clay lenses. Holocene.
	Sunderland Formation	0 – 20	Poorly sorted sediments ranging from clay and sandy clay to basal gravel. Pliocene.
Black Creek Aquifer	Black Creek Formation	50 – 100	Gray to black thinly laminated montmorillonite clays interbedded with glauconitic sand lenses. Upper Cretaceous.
Cape Fear Aquifer	Cape Fear Formation	30 – 80	Light colored, poorly sorted sands and montmorillonitic, feldspathic clays. Lower Cretaceous.
Basement Rock	Pre–Cretaceous Bedrock	NA	Igneous and metamorphic crystalline rock. Precambrian.

FIGURE 2.1

GENERAL HYDROGEOLOGIC SECTION

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

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present at the site. Depending on the type of soil, site conditions, and experience of the crew operating the equipment, CPT can provide large amounts of data for a minimum of the cost of actual soil borings.

CPT was conducted using the USACE SCAPS truck, which consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is mounted inside to a 3-axle Kenworth chassis. The truck weight can achieve an overall push capability of 43,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the pushrods, rather than by the weight of the truck. The current 43,000-pound limitation is intended to minimize the possibility of pushrod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer has a 1.4-inch outside diameter(OD), 60-degree conical tip, and a 1.4-inch-OD by 6-inch-long friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell inside the probe is a cylinder of uniform cross section which is instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data is digitized, recorded, and plotted by computer in the penetrometry truck. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 inches per minute (2 cm/s), although this rate must sometimes be reduced when hard layers are encountered. Penetration, dissipation, and resistivity data will be used to determine site layering as it is encountered in the field.

The CPT apparatus is capable of placing a variety of well types to collect groundwater samples. Permanent monitoring points and temporary sampling points can be installed by the pushrod of the CPT as it descends into the subsurface. Placement of such points is useful because groundwater samples can be taken at several depths very quickly. Polyvinyl chloride (PVC) casing is inserted into the hollow center of each section of the pushrod and lowered into the subsurface to construct a fully cased well. A sacrificial tip on the end of the pushrod anchors the PVC screen and casing into the soil as the pushrod is extracted. Such sampling points are constructed with 1 meter of slotted PVC screen. Groundwater samples are collected with a peristaltic pump and polyethylene tubing.

Grab samples of water can also be collected using the CPT equipment without placement of screens by extracting water from the center of the penetrometer rod itself. The penetrometer rod is lowered to the desired depth, and then withdrawn 2 to 3 feet to allow water to enter the vacated space left by the penetrometer tip. A tube or a bailer inserted to the bottom of the rod is then used to extract the groundwater.

The known ability of aromatic or chlorinated hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology in conjunction with CPT technology to detect soil characteristics and hydrocarbon contamination simultaneously. The CPT/LIF system has a nitrogen-based laser optics fluorometer tool that allows a laser to scan the soil for fluorescent compounds as the CPT/LIF penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are co-solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. Optimal wavelengths to be used during a continuous CPT push will be determined from initial data. Wavelength is selected to give the strongest fluorescence signal, which can be attributed to the presence of contamination. Past experience suggests that a short wavelength of less than 275 nanometers (nm) may be appropriate for detecting the fluorescence of BTEX.

The purpose of the CPT/LIF sampling at the former AGE fuel facility site was to provide a preliminary determination of the subsurface stratigraphy, to help delineate the areal extent of the free- and residual BTEX plumes, and to place temporary monitoring points. The CPT/LIF data will be used to optimally place groundwater monitoring points and soil sampling points for delineation of the mobile and residual (LNAPL) plumes, and the dissolved BTEX plume in shallow groundwater. This more detailed delineation will be performed using the Geoprobe® system.

2.1.3.1 Sampling Strategy

The general area to be investigated was determined from information provided at the January 10, 1995 meeting at Seymour Johnson AFB. Because little data have been collected at the site and no formal reports have been prepared, Parsons ES and USACE performed the preliminary assessment, which will be augmented by the more detailed investigation described in Section 3. Based upon the UST closure information, the former location of the USTs was the only area known to be contaminated. As a result, sample locations progressed outward from this point in all directions. All necessary digging and access permits were obtained by Seymour Johnson AFB personnel prior to

Parsons ES mobilizing to the field. This included the identification of utility lines, USTs, fuel lines, and other underground infrastructure before CPT operations commenced.

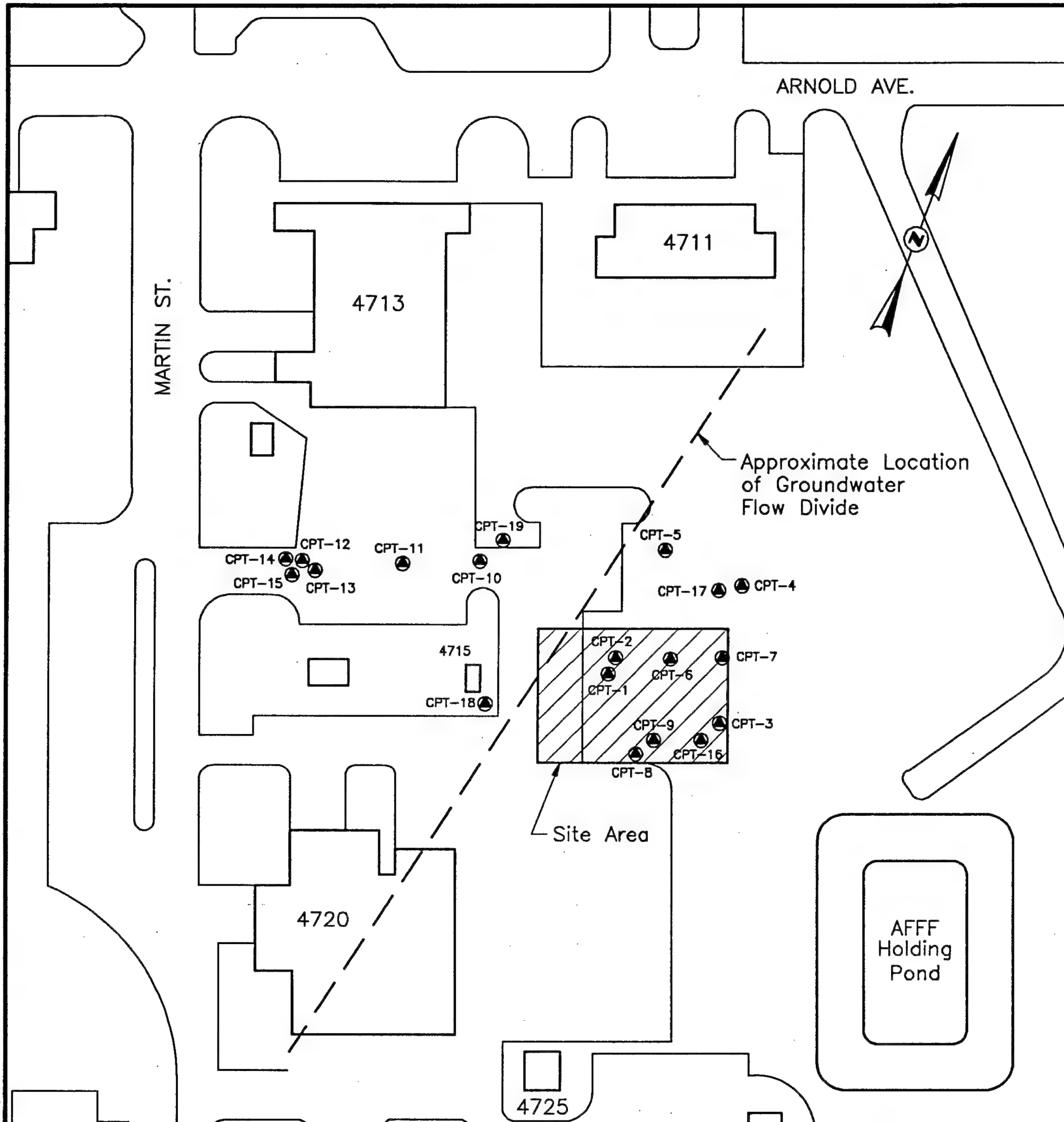
CPT/LIF data were used for preliminary delineation of the areal and vertical extent of mobile- and residual fuel hydrocarbons in the unsaturated zone at the former AGE fuel facility site. The cone penetrometer with the LIF assembly was pushed from ground surface to below petroleum hydrocarbon contamination as sensed by the LIF probe, or up to approximately 30 feet bgs, depending on contaminant distribution. The CPT test locations are shown on Figure 2.2. Data from 19 test locations were collected; 10 were performed with both CPT and LIF equipment (CPT-2 through CPT-8, and CPT-10 through CPT-12). At 4 locations (CPT-9 and CPT-13 through CPT-15), soil samples were collected for qualitative assessment of soil contamination. The CPT/LIF data are provided in Appendix A. Temporary monitoring points were installed at four locations (CPT-16 through 19). CPT-1 was a push without a probe to determine if a concrete hold down pad was left in the former UST impoundment after the tanks were removed and the excavation backfilled.

2.1.3.2 Decontamination Procedures

The CPT push rods were cleaned with USACE's CPT steam-cleaning system as the rods were withdrawn from the ground. Rinseate was generated only as the rods moved past the cleaner, thereby minimizing liquid waste generation. Care was taken not to apply the pressurized steam to the LIF module. Rinseate was collected in 55-gallon drums provided by Seymour Johnson AFB. Filled drums were transported to an oil/water separator located near the former AGE fuel facility site for proper water disposal, as designated by Seymour Johnson AFB.

2.1.4 Soil Quality

Preliminary characterization of the vadose zone and shallow aquifer system at the former AGE fuel facility site was the objective of the preliminary site screening performed by Parsons ES and USACE. The CPT/LIF data obtained at the site indicated the possible presence of mobile and residual hydrocarbons near the former USTs. In addition, a somewhat larger area of contaminated soil was indicated. Preliminary delineation of subsurface hydrocarbon contamination at the site is shown on Figure 2.3. No soil samples were collected for laboratory analysis during the



LEGEND

CPT-1 ● CPT test location.

Note: Locations approximate; have not been surveyed.

100' 50' 0 100'

Approximate Scale in Feet

FIGURE 2.2

CPT TEST LOCATIONS

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

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Cary, North Carolina

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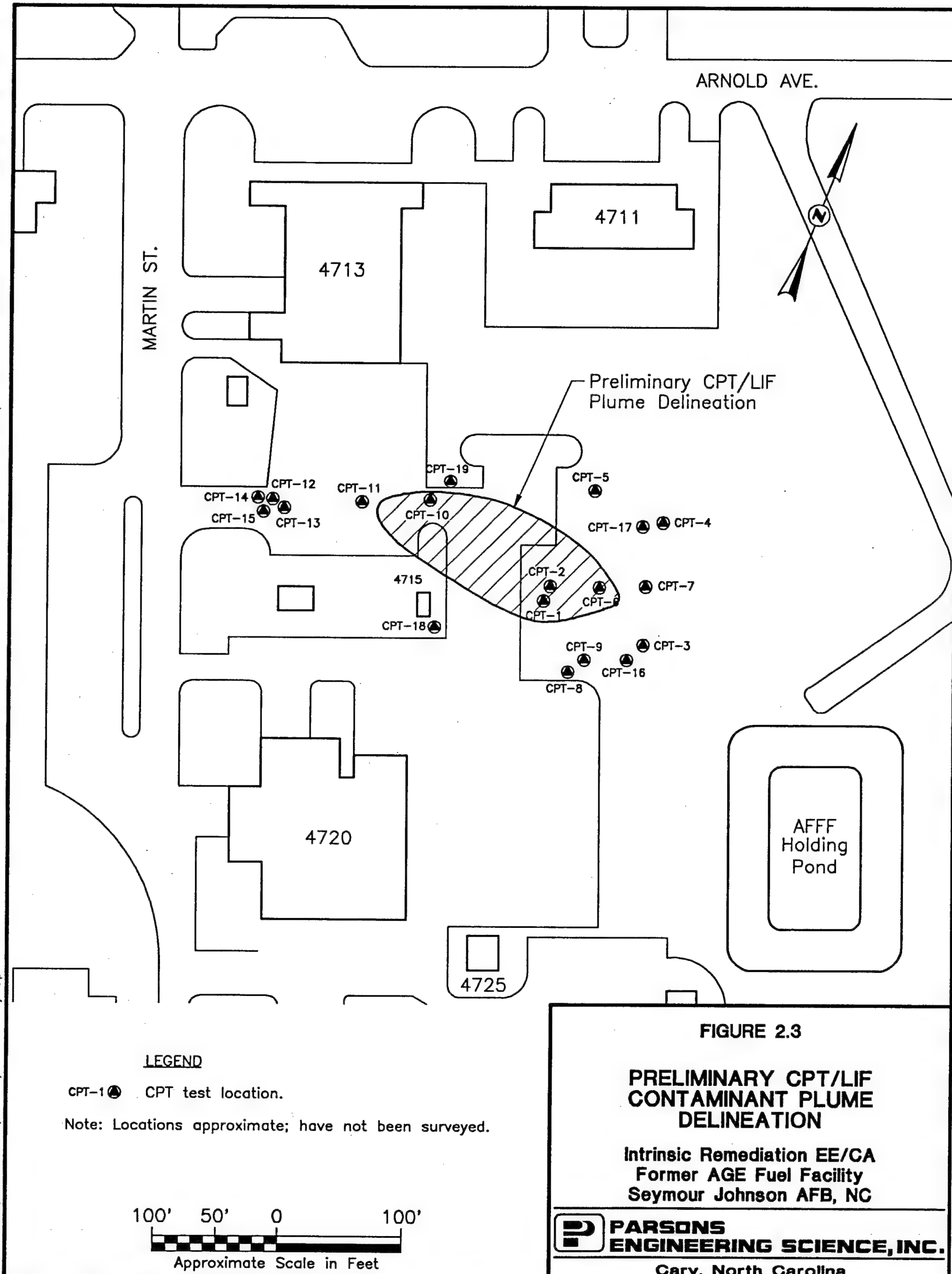

FIGURE 2.3

PRELIMINARY CPT/LIF CONTAMINANT PLUME DELINEATION

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

preliminary site screening. The presence of mobile hydrocarbons and residual soil contamination will be determined during the proposed field activities.

2.1.5 Groundwater Quality and Chemistry

To date, no groundwater samples have been collected at the site for laboratory analysis. The proposed field activities will include groundwater sampling activities which conform to North Carolina guidelines.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

The former AGE fuel facility site conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data so that a coherent representation of the groundwater flow and contaminant transport system can be developed. The conceptual model will be used to aid in locating additional data collection points and to help develop the Bioplume II model.

Successful conceptual model development involves:

- Definition of the problem to be solved;
- Model selection;
- Designing the conceptual model;
- Integrating available data, including:
    - Local geologic and topographic data,
    - Hydraulic data,
    - Site stratigraphy,
    - Contaminant concentration and distribution data; and
- Determining additional data requirements.

2.2.1 Conceptual Model Design Components

Site hydrogeologic data will be developed in detail during the field investigations. The general hydrogeologic section (Figure 2.1) shows, in limited detail, the relationships between hydrostratigraphic units (i.e., transmissive units and aquitards). Detailed data on the nature and spatial extent of contamination will be developed. The direction or directions of groundwater flow and contaminant transport will be fully investigated.

If free product is found to be present at the site, it may be necessary to use the fuel/water partitioning model of Bruce et al. (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the groundwater. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

Based on available data, Parsons ES expects to model the site as an unconfined fine- to coarse-grained sandy aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater surface discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. Such information can be obtained from Seymour Johnson AFB maps which delineate areas that may facilitate rapid subsurface transport and/or surface discharge. Pathways to potential receptors may include discharge of contaminated groundwater into downgradient surface water bodies (e.g., drainageways, Stoney Creek, and the Neuse River), and migration of the contaminant plume toward downgradient potable and nonpotable water wells.

Potential human and/or ecological receptors of BTEX contamination in groundwater will be identified. No jurisdictional wetlands are present on Seymour Johnson AFB. No designated ecologically sensitive habitat has been identified at the site. Three endangered species have been identified in the area; the Red-Cockaded Woodpecker, the Peregrine Falcon, and the Neuse River Waterdog (Law Environmental, 1992). No groundwater wells are used for potable water supply at Seymour Johnson AFB. Groundwater from the Black Creek and Cape Fear Aquifers is used for domestic, industrial, and public water supply, but is not exploited for these purposes in the area

immediately surrounding Seymour Johnson AFB (Law Environmental, 1992). The closest well for potable use was found to be approximately 3 miles from the base (Law Environmental, 1992). Hence, the probable impact of site contamination on potable groundwater supplies is low. Because the groundwater at the former AGE fuel facility site is hydrogeologically connected to the Neuse River and Stoney Creek (and their minor tributaries which flow through the base), it may be necessary to survey the area outside the immediate vicinity of the site to identify any river marshes or other possible receptors.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the EE/CA and to evaluate whether natural attenuation of site-related contaminants is occurring at the former AGE fuel facility site, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the EE/CA.

Physical hydrogeologic characteristics include:

- Depth from measurement datum to the groundwater surface in monitoring points;
- Depth from measurement datum to the base of the shallow saturated zone (where feasible);
- Locations of potential groundwater recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of free- and residual-phase product.

Chemical hydrogeologic characteristics include:

- Dissolved oxygen (DO) concentration;
- Specific conductance;
- pH;
- Reduction/oxidation potential (redox);

- Chemical analysis of free product to determine mass fraction of BTEX; and
- Chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

In order to obtain these data, cone penetrometer testing (CPT) in conjunction with laser-induced fluorometry (LIF) has been performed at the former AGE fuel facility site during a preliminary site screening investigation. In addition, the AFCEE Geoprobe® will be used for the installation of groundwater monitoring points and for soil and groundwater sampling at the site in support of the EE/CA. This work is to take place in April 1995. Groundwater and free product samples will also be collected, as needed, to support the intrinsic remediation option. The following sections describe the procedures that will be followed when collecting additional site-specific data. Geoprobe® soil sampling procedures are described in Section 3.1. Procedures to be used for the installation of permanent monitoring points and temporary sampling points are described in Section 3.2. Procedures to be used for groundwater sampling are described in Section 3.3. Aquifer parameters (i.e., hydraulic conductivity) will be measured using the procedures described in Section 3.4.

3.1 SOIL SAMPLING

The following sections describe sample collection techniques, sampling locations, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Sample Collection Using the Geoprobe® System

The Geoprobe® system is a hydraulically powered percussion/probing machine used to advance sampling tools through unconsolidated soils. This system provides for the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.1 is a diagram of the Geoprobe® system. The following sections describe soil sample collection methods and decontamination methods for use with the Geoprobe® system.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUNDWATER AND SOIL SAMPLES
INTRINSIC REMEDIATION EE/CA

SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008 (or similar)	F
Ferrous Iron (Fe^{+2})	Colorimetric, HACH Method 8146 (or similar)	F
Ferric Iron (Fe^{+3})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034 (or similar)	F
Sulfide	Colorimetric, HACH Method 8131 (or similar)	F
Sulfate	Colorimetric, HACH Method 8051 (or similar)	F
Nitrate	Titrimetric, HACH Method 8039 (or similar)	F
Nitrite	Titrimetric, HACH Method 8507 (or similar)	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Alkalinity (Carbonate [CO_3^{-2}] and Bicarbonate [HCO_3^{-1}])	Titrimetric, HACH Method 8221 (or similar)	F
Carbon Dioxide	CHEMetrics Method 4500	F
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Alkalinity	E150.1	L
Methane	RSKSOP175	L
Total Organic Carbon	A5310C	L
Aromatic Hydrocarbons (Including Trimethylbenzene and Tetramethylbenzene)	SW8020 (RSKSOP-133) (substitute for EPA602)	L
Total Hydrocarbons	SW8015, modified	L
Volatile Organics	GC/MS method, SW8240 (subst. for EPA601)	L
Polycyclic Aromatic Hydrocarbons	GC/MS method, SW8270 (subst. for EPA625)	L
Total Lead	using 3030C preparation method	L
Free Product	GC/MSD fuel identification	L
Ammonia–Diss. Gas in Water	RSKSOP	L
SOIL		
Total Organic Carbon	SW9060	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015, modified	L

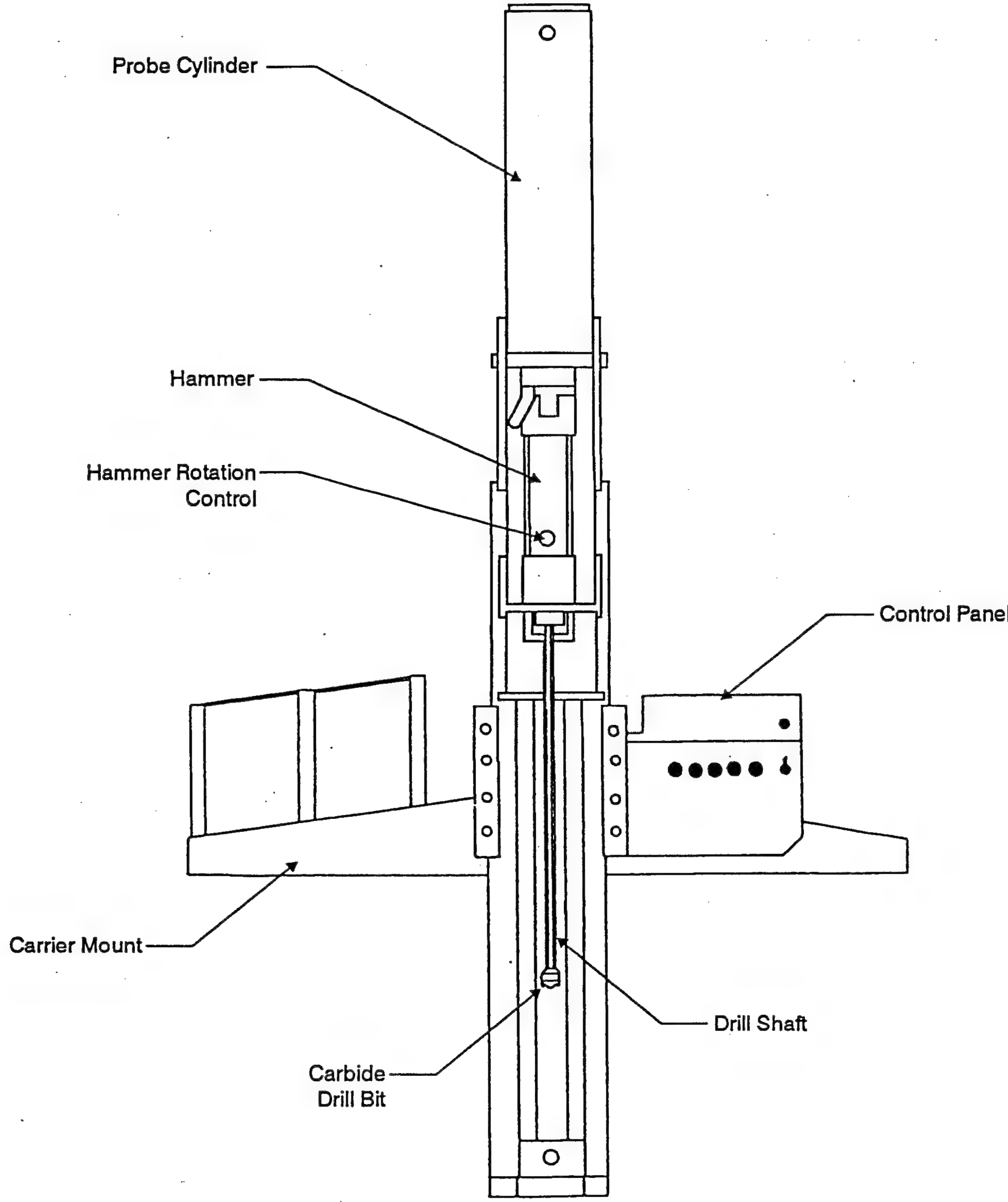

FIGURE 3.1

CROSS SECTION OF GEOPROBE

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

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Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted, which opens the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for logging or the liners can be capped and undisturbed samples submitted to the analytical laboratory for testing.

If the probe-drive sampling techniques described above are inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional sore boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.2. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

GEOLOGIC BORING LOG

BORING NO.: ______ CONTRACTOR: ______ DATE SPUD: ______
CLIENT: AFCEE RIG TYPE: ______ DATE CMPL.: ______
JOB NO.: 722450.26 DRLG METHOD: ______ ELEVATION: ______
LOCATION: SEYMOUR JOHNSON AFB BORING DIA.: ______ TEMP: ______
GEOLOGIST: ______ DRLG FLUID: ______ WEATHER: ______
COMMENTS: ______

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
	5											
	10											
	15											
	20											
	25											
	30											

NOTES
- bgs – Below Ground Surface
- GS – Ground Surface
- TOC – Top of Casing
- NS – Not Sampled
- SAA – Same As Above

SAMPLE TYPE
- D – DRIVE
- C – CORE
- G – GRAB

▼ Water level drilled

FIGURE 3.2

GEOLOGIC BORING LOG

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

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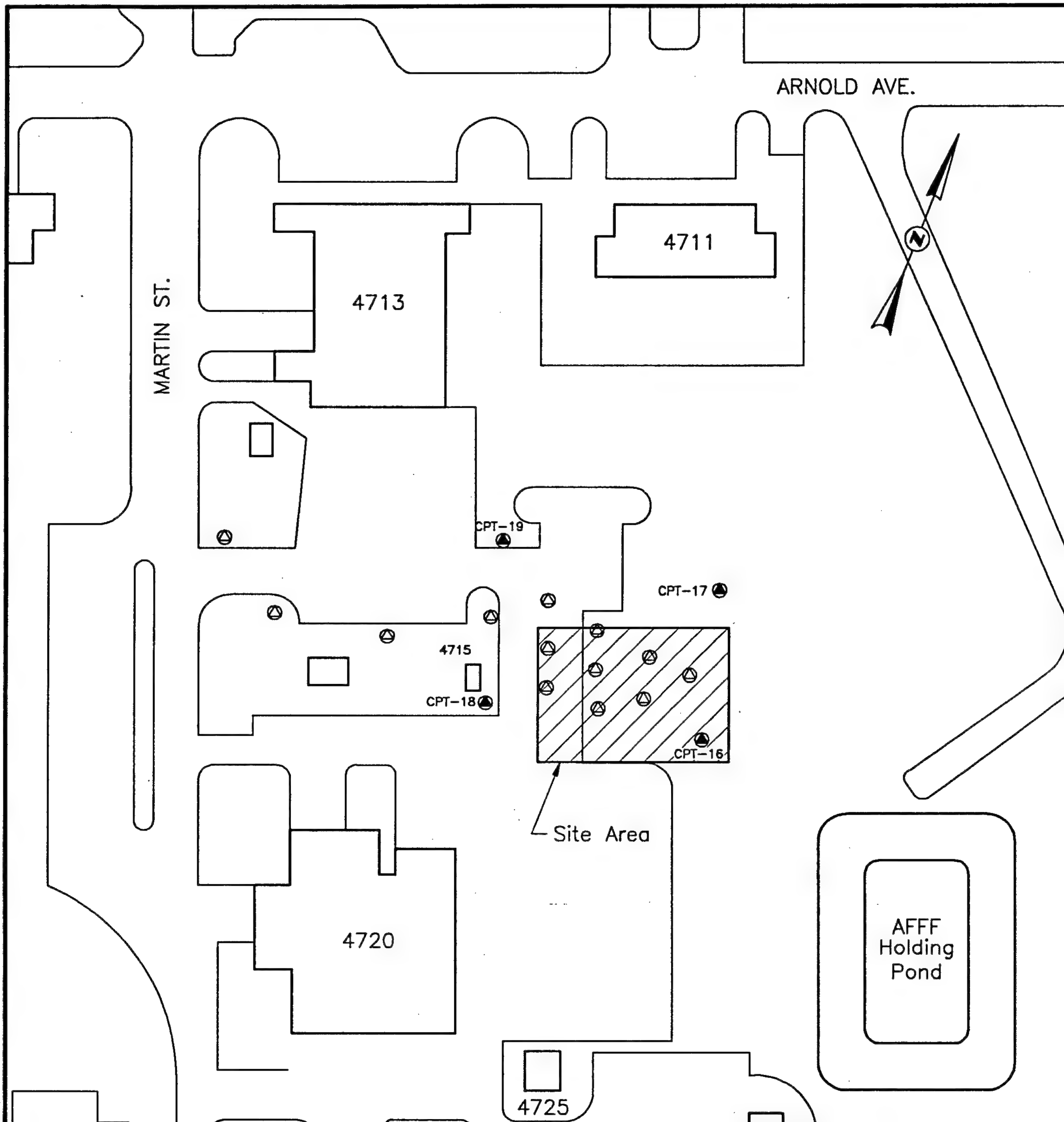
Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Parsons ES will be responsible for providing trained operators for the Geoprobe®.

3.1.2 Soil Sample Locations and Required Analyses

This section identifies the proposed locations for soil sampling at the former AGE fuel facility site at Seymour Johnson AFB. Table 3.1 presents an analytical protocol for ground water and soil samples, and Appendix A contains detailed information on the analyses and methods used during this sampling effort.

Soil samples will be collected at selected Geoprobe® and monitoring point installation locations. Figure 3.3 identifies the proposed soil sampling and monitoring point installation locations at the former AGE fuel facility site. At least one sample will be collected from each hole punched, at the depth of maximum BTEX contamination as determined by soil headspace screening. In selected holes, one additional sample will be taken at the water table. Additional samples and sampling intervals will be collected at the discretion of the Parsons ES scientist. A total of 20 soil samples will be collected for laboratory analysis.

A portion of the sample will be sent to the laboratory for analytical analysis while another portion of the sample will be utilized to determine soil headspace. Each laboratory soil sample will be placed in an analyte-appropriate sample container and shipped to the analytical laboratory for analysis of total hydrocarbons, aromatic hydrocarbons, and moisture content using the procedures presented in Table 3.1. In addition, four samples will be analyzed for total organic carbon (TOC) from uncontaminated locations upgradient of the contaminant source. Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to sit for at least 5 minutes. Soil headspace will then be determined using an organic vapor meter (OVM), and the results will be recorded in the field records by the Parsons ES field scientist.



LEGEND

CPT-16 CPT-installed monitoring points.

Proposed locations for shallow and deep monitoring points and soil sampling.

100' 50' 0 100'

Approximate Scale in Feet

FIGURE 3.3

PROPOSED MONITORING POINT LOCATIONS

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

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3.1.3 Datum Survey

The horizontal location of all soil sampling locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured to the nearest 0.1 foot relative to USGS msl data.

3.1.4 Site Restoration

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Holes created by the Geoprobe® in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the penetrometer rod will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the Geoprobe® creates low volumes of soil waste. Soil not used for sampling will be placed in 55-gallon drums provided by the Base and disposed of by Base personnel. Alternate methods of soil waste disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinseate will be collected in 55-gallon drums provided by the Base and later transported to and disposed of in the oil/water separator near the former AGE fuel facility site as designated by Base personnel.

Between each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox® and potable water. The barrel will then be rinsed with deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination.

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the sample hand auger, shovel, drive sampler, drive sample sleeves, and other equipment or portions thereof that will

contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with reagent-grade isopropyl alcohol; and,
- Rinse with distilled or deionized water;
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook.

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the laboratory's permanent record of the sampling event.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.1.6 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for soil

headspace screening and for onsite measurements of oxygen, temperature, conductivity, and pH.

3.2 MONITORING POINT INSTALLATION

To provide information regarding contaminant distribution and concentrations and groundwater elevations at the site, monitoring points will be installed. While the North Carolina Department of Environment, Health, and Natural Resources requires that permanent monitoring wells follow specific construction guidelines, it is possible to use wells constructed in the manner of monitoring points. Monitoring points (as outlined in Section 3.2.2) will be installed in selected locations and developed as described in Sections 3.2.4 and 3.2.5. Sampling of these monitoring points will follow procedures outlined in Section 3.3.

3.2.1 Monitoring Point Locations and Completion Intervals

Data collected during the preliminary site screening investigation were reviewed to determine the proposed locations for monitoring points. Shallow monitoring points will be placed so that the screened intervals straddle the water table. Deep monitoring points will be placed at least 5 feet below the bottom of the shallow monitoring point screen. The locations of proposed monitoring points and the completion intervals presented below are tentative and may be adjusted at the discretion of the Parsons ES field scientist. Permanent monitoring points will be used for long-term monitoring to track migration of dissolved BTEX and/or mobile LNAPL from the former AGE fuel facility site. Temporary monitoring points may be interspersed throughout the suspected area of contamination to further describe the horizontal and vertical distribution of hydrocarbons in support of the natural attenuation remedial option. A more detailed description of the locations and completion intervals is described in the following sections.

3.2.1.1 Permanent Monitoring Points

Six to eight permanent multi-depth monitoring points may be installed to further characterize and monitor groundwater quality at the site. Proposed locations for these points were determined from a review of data compiled from the preliminary site screening investigation. Final monitoring point locations will be based on the initial results of the proposed field work.

3.2.1.2 Temporary Monitoring Points

In addition to the permanent monitoring points to be installed at the former AGE fuel facility site, up to seven temporary monitoring points may be installed to fully delineate the extent of hydrocarbon contamination. Possible locations of temporary monitoring points are indicated on Figure 3.3. These locations will be selected to provide geochemical and hydrogeologic data necessary for successful implementation of the Bioplume II® model. For some locations, two screened depths, with 1 meter of screen each, will allow vertical delineation of the dissolved groundwater plume.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, drilling, and groundwater monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination Procedures

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points, tubing, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water prior to use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon® tubing connected to a 0.5-inch diameter stainless steel screen or a 0.5-inch inside diameter (ID)/0.75-inch outside diameter (OD) PVC screen and casing.

3.2.2.3.1 Deep Monitoring Points

The deep monitoring points will be installed in boreholes punched using the Geoprobe® system. The deep monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch diameter stainless steel mesh that functions as the well screen, which is connected to 0.375-inch Teflon® tubing.

To install the deep monitoring points, the borehole is punched and sampled to several feet above a target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon® tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly and tubing behind. The saturated soil formation is likely to cave in around the screen assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point. The borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to form a seal to the ground surface.

3.2.2.3.2 Shallow Monitoring Points

If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch OD/0.5-inch ID PVC casing and well screen to provide additional water level information. Approximately 1 meter of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole is staying open. If the borehole remains open, the 0.5-inch ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Temporary monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch

MONITORING POINT INSTALLATION RECORD

JOB NAME SEYMOUR JOHNSON AIR FORCE BASE MONITORING POINT NUMBER ____________

JOB NUMBER 722450.26 INSTALLATION DATE ____________ LOCATION ____________

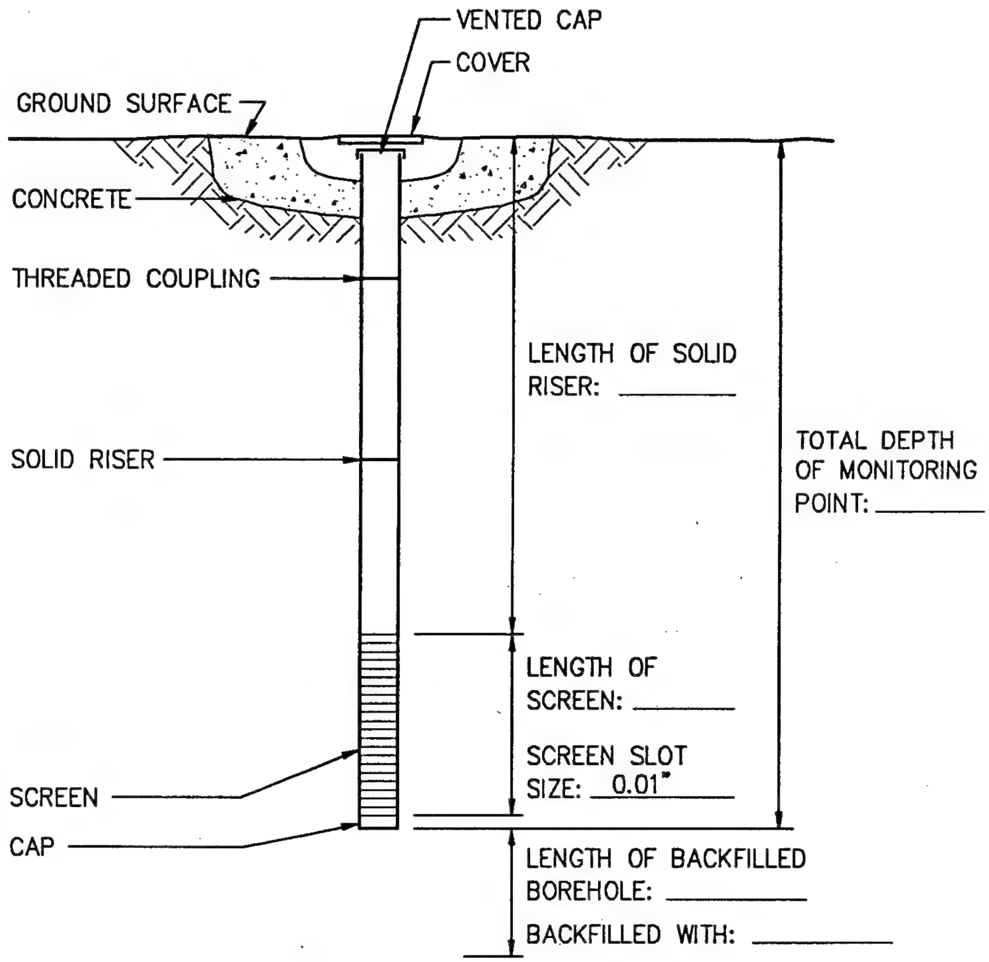
DATUM ELEVATION ____________ GROUND SURFACE ELEVATION ____________

DATUM FOR WATER LEVEL MEASUREMENT ____________

SCREEN DIAMETER & MATERIAL ____________ SLOT SIZE ____________

RISER DIAMETER & MATERIAL ____________ BOREHOLE DIAMETER ____________

CONE PENETROMETER CONTRACTOR ____________ ES REPRESENTATIVE ____________



(NOT TO SCALE)

STABILIZED WATER LEVEL ____________ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ________ FEET BELOW DATUM.

GROUND SURFACE ____________ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

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openings. Monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5-inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

If subsurface conditions do not permit the boreholes to stay open (i.e. the formation collapses in the hole), shallow 0.5 inch-ID PVC monitoring points may be installed using the Geoprobe®. If the installation of 0.5-inch PVC monitoring points is not possible or is impractical using the Geoprobe®, monitoring points constructed of 0.375 inch Teflon® described in Section 3.2.2.3.1 will be utilized. Should 0.5-inch ID PVC shallow monitoring points not be installed, the only data gap resulting will be the lack of water level information for that particular location. As a back up to installation of monitoring points with the Geoprobe®, a decontaminated stainless steel hand auger will be used to install up to four monitoring points for water level data collection. At present, four monitoring points installed by the USACE SCAPS truck are available at the site for water level data collection. The decision to install 0.5-inch ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.4 Monitoring Point Completion

A number of the monitoring points will be completed abovegrade, and steel protective casing will be used to protect the well points from tampering and damage. Where pavement is present, an at-grade cover will be cemented in place using concrete blended into the existing pavement. Where pavement is not present, the protective cover will be raised slightly above the ground surface with a 1-foot square concrete pad that will slope gently away from the cover to facilitate runoff during precipitation events. The number of permanent monitoring points will be determined by the Parsons ES field scientist.

3.2.2.5 Monitoring Point Abandonment and Site Restoration

After monitoring point installation and sampling is complete, the site will be restored as closely as possible to its original condition. Clean and contaminated development waters and sampling purge waters will be stored in 55-gallon drums provided by the Base and transported to the designated oil/water separator for disposal.

Those monitoring points not completed with an external casing will be abandoned. The PVC casing and screen or Teflon® tubing will be extracted as far as possible and discarded. While holes created by the Geoprobe® in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive rod, any test holes remaining open after extraction of the casing will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the ground water.

3.2.3 Monitoring Point Development and Records

The monitoring points will be developed prior to sampling to remove fine sediments from the portion of the formation adjacent to the well point screen. Development will be accomplished using a peristaltic pump provided by Parsons ES. The pump will be attached to the well point where 0.375-inch Teflon® tubing is used; where PVC points are installed, dedicated high-density polyethylene (HDPE) tubing will be inserted into the point and attached to the pump. Water will be removed until pH, temperature, specific conductivity, and water clarity (turbidity) stabilize. Monitoring point development will occur a minimum of 24 hours prior to sampling.

Development waters will be collected in 55-gallon drums provided by the Base. Filled 55-gallon drums will be transported designated oil/water separator for disposal.

A development record will be maintained for each monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point number;
- Date and time of development;

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: ____________________ Job Name: ________________________

Location ____________________ By____________________ Date________

Well Number____________________ Measurement Datum____________________

Pre-Development Information Time (Start):

Water Level: Total Depth of Well:

Water Characteristics

Color____________________ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material____________________________

pH____________ Temperature(^{O}F ^{O}C) ____________

Specific Conductance(µS/cm)________________________

Interim Water Characteristics

Gallons Removed

pH

Temperature (^{O}F ^{O}C)

Specific Conductance(µS/cm)

Post-Development Information Time (Finish):

Water Level: Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color____________________ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material____________________________

pH____________ Temperature(^{O}F ^{O}C) ____________

Specific Conductance(µS/cm)________________________

Comments:

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

Intrinsic Remediation EE/CA
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- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the well points will be surveyed soon after completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the protective casing will be measured relative to the USGS msl datum. The ground surface elevation will be measured to the nearest 0.1 foot. Because water levels cannot be measured through the well point tubing, no datum elevation, such as top of casing, will be measured for points installed using 0.375-inch Teflon® tubing. If PVC points are installed, the top of the PVC casing will be measured to the nearest 0.01 foot.

3.2.5 Water Level Measurements

Where possible, water levels at monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples at monitoring points. This section also details grab-sampling using peristaltic pump tubing inserted into the probe rods to obtain single, discrete groundwater samples, if required. All groundwater samples will be obtained using a peristaltic pump and dedicated Teflon®-lined, polyethylene tubing where groundwater

levels permit. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference.

The following summarizes the activities that will occur during groundwater sampling:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well or monitoring point integrity including:
  - Protective cover, cap, and lock,
  - External surface seal and pad,
  - Monitoring point stick-up, cap, and datum reference, and
  - Internal surface seal;
- Groundwater sampling, including:
  - Water level and product thickness measurements,
  - Visual inspection of sample water,
  - Monitoring point casing evacuation, and
  - Sample collection;
- Sample preservation and shipment, including:
  - Sample preparation,
  - Onsite measurement of physical parameters, and
  - Sample labeling;
- Completion of sampling records; and

- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Groundwater Sampling Strategy

Groundwater samples will be collected from monitoring points installed during this project. The monitoring point locations for sampling are identified in the following sections. If site conditions prevent the installation of monitoring points, discrete grab samples will be acquired through the probe rod at each of the proposed monitoring point locations. Up to 30 groundwater samples will be collected for laboratory analysis.

3.3.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before use. This includes the Geoprobe® rods, water-level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with reagent-grade isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling form (Figure 3.6). If precleaned, dedicated sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory, and therefore will not need to be cleaned in the field. The type of container provided and the method of container decontamination will be documented in the analytical laboratory's permanent record of the sampling event.

3.3.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite measurements of oxygen, carbon dioxide, pH, electrical conductivity, temperature, reduction/oxidation potential, sulfate, nitrate, nitrite, ferrous iron (Fe^{2+}), total iron, and manganese. Ferric iron (Fe^{3+}) will be calculated from the concentration of total iron minus ferrous iron.

3.3.3 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient cleaning of equipment between monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.2.1. In addition to the use of properly cleaned equipment, dedicated polyethylene tubing will be used at each sampling point, and a clean pair of new, disposable nitrile gloves will be worn each time a different monitoring point is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

SAMPLING LOCATION ____________
SAMPLING DATE(S)____________

GROUND WATER SAMPLING RECORD - MONITORING WELL ____________________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ____________, 19__ : ________ a.m./p.m.
SAMPLE COLLECTED BY: __________________ of ________________
WEATHER:____________________________________
DATUM FOR WATER DEPTH MEASUREMENT (Describe):____________________

MONITORING WELL CONDITION:
[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS:____________________
INNER PVC CASING CONDITION IS:____________________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe):____________________

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH____________________
Items Cleaned (List):____________________

2 [ ] PRODUCT DEPTH ____________________FT. BELOW DATUM
Measured with:____________________

WATER DEPTH ____________________FT. BELOW DATUM
Measured with:____________________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance:____________________
Odor:____________________
Other Comments:____________________

4 [ ] WELL EVACUATION:
Method:____________________
Volume Removed:____________________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors:____________________
Other comments:____________________

m:\forms\gwsample.doc
Page 1 of 2

FIGURE 3.6

GROUND WATER SAMPLING RECORD

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

DATA\95DWG\950009.DWG / 1=1 / 3-15-95 / tlp

Ground Water Sampling Record - Monitoring Well No. ______________ (Cont'd)

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of: ______________________________

[ ] Pump, type: _

[ ] Other, describe: ______________________________

Sample obtained is [ ] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Temp: ________ ° ______	Measured with: ______________
pH: ______________	Measured with: ______________
Conductivity: ________	Measured with: ______________
Dissolved Oxygen: ________	Measured with: ______________
Redox Potential: ________	Measured with: ______________
Salinity: ________	Measured with: ______________
Nitrate: ________	Measured with: ______________
Sulfate: ________	Measured with: ______________
Ferrous Iron: ________	Measured with: ______________

Other: ______________________________

7 [ ] SAMPLE CONTAINERS (material, number, size): ______________________________

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration:

Method ____________	Containers: ____________
Method ____________	Containers: ____________
Method ____________	Containers: ____________

[ ] Preservatives added:

Method ____________	Containers: ____________
Method ____________	Containers: ____________
Method ____________	Containers: ____________
Method ____________	Containers: ____________

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled

[ ] Container Lids Taped

[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS: ________

FIGURE 3.6
(Continued)

GROUND WATER SAMPLING RECORD

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

m:\forms\gwsample.doc

Page 2 of 2

3.3.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the sampled monitoring point.

3.3.3.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring point, the static water level will be measured, if possible. An electrical water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring point and the depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the monitoring point will be calculated. In the case of points with Teflon® tubing casing and stainless steel screens, purge volumes will be calculated based on the known screen volume. If free product is encountered, the thickness of the product will be measured if possible. Attempts will be made to sample both within and below the oil lens.

3.3.3.3 Purging Before Sampling

The volume of water contained within the monitoring point casings at the time of sampling will be calculated, and three times the calculated volume will be removed from the monitoring point. All purge water will be placed in Base-provided, 55-gallon drums and disposed of into Seymour Johnson AFB's oil/water separator collection drain or at other approved locations. Emptied drums will handled by Base personnel. A peristaltic pump will be used for monitoring point purging.

If a monitoring point is evacuated to a dry state during purging, the monitoring point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

The installed well points require minimal purging before sampling because the water in the well point tubing has little contact with the atmosphere. The sampler will pump

enough water to ensure that the water in the tubing has been changed several times and that DO, redox potential, specific conductance, and pH stabilize.

3.3.3.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from the monitoring. The tubing will be lowered through the well and 0.5-inch ID PVC monitoring point casing into the water gently to prevent splashing. The tubing from the monitoring points constructed of 0.375-inch Teflon® tubing will be connected directly to the peristaltic pump. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

At locations where the installation of monitoring points is found to be impossible, inefficient, or inadequate to acquire a credible groundwater sample, grab groundwater sampling will be performed using the Geoprobe®, peristaltic pump, and dedicated HDPE tubing. The tubing will be lowered into a push rod fitted with a slotted tip and a discrete groundwater sample will be acquired.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for monitoring point purge waters and transported for disposal to the oil/water separator drain located near the site unless instructed otherwise by Seymour Johnson AFB personnel.

3.3.4 Onsite Groundwater Parameter Measurement

As indicated in Table 3.1, many of the groundwater chemical parameters will be measured onsite by Parsons ES personnel. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH® portable colorimeter in accordance with specific HACH® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox® and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the

groundwater sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled to identify their contents and carefully stored for later transfer by Base personnel to an approved disposal facility.

3.3.4.1 Dissolved Oxygen Measurements

DO measurements will be taken using a meter with a down-hole oxygen sensor or a sensor in a flow-through cell. Measurements will be taken before, and immediately following groundwater sample acquisition. When DO measurements are taken in a monitoring point that has not yet been sampled, the monitoring point will be purged until DO levels stabilize.

3.3.4.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded on the groundwater sampling record (see Figure 3.6). As space allows, probes for these analyses will be placed in the same flow-through cell used for DO measurements.

3.3.4.3 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by experienced Parsons ES scientists via titrimetric analysis using CHEMetrics® Method 4500-CO_2C (10-100 ppm as CO_2).

3.3.4.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced Parsons ES scientists via titrimetric analysis using EPA-approved HACH® method 8221 (0-5,000 mg/L as calcium carbonate).

3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced Parsons ES scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® method 8039 (0-30.0 mg/L nitrate). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH® method 8507 (0-0.35 mg/L nitrite).

3.3.4.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. The Parsons ES scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. EPA-approved HACH® methods 8051 (0-70.0 mg/L sulfate) and 8131 (0.60 mg/L sulfide) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® method 8008 for total soluble iron (0-3.0 mg/L ferric and ferrous iron) and HACH® method 8146 for ferrous iron (0-3.0 mg/L) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.4.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantified in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. EPA approved HACH® method 8034 (0-20.0 mg/L) will be used to prepare the samples for quantification of manganese concentrations.

3.3.4.9 Reduction/Oxidation Potential

The reduction/oxidation (redox) potential of groundwater is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should have a redox potential somewhat less than that taken in the upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis. As space allows, the redox probe will be placed in the same flow-through cell used for DO measurements.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples to be performed by Parsons ES personnel from the time of sampling until the samples arrive at the laboratory.

3.4.1 Sample Preservation

The analytical laboratory support personnel will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees Centigrade (°C).

Samples will be promptly delivered to the analytical laboratory via overnight courier so that all sample holding times are met.

3.4.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the analytical laboratory (see Appendix B). The sample containers will be filled as described in Sèctions 3.3.3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to analytical laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container; and
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by overnight courier to the analytical laboratory. Delivery will occur shortly after sample acquisition.

3.4.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the analytical laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sample collector after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance, and
  - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total monitoring well/point depth;
- Purge volume;
- Water level after purging;
- Monitoring well/point condition;
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity; and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater samples and the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, arrangements will be made with the analytical

laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA protocol or those listed in Appendix B of this plan.

Analytical laboratory support personnel will specify the necessary QC samples and notify the laboratory to prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to transportation. Containers, ice chests with adequate padding, and cooling media may be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

3.5 AQUIFER TESTING

If sufficient data are not available from previous studies at the site, Parsons ES may be required to perform hydraulic conductivity testing. Three monitoring wells installed at an IRP site approximately 800 feet from the former AGE fuel facility site (at Building 4745) are available for slug testing. These three wells are completed into the surficial aquifer and did not detect groundwater contamination at the site. Well installation and construction information are available for the wells in Law Environmental (1989). Slug tests will be conducted by Parsons ES personnel to estimate the hydraulic conductivity of the shallow saturated zone. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; for the Seymour Johnson AFB site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.

- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.

- **Slug Test.** Two types of testing are possible; a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.

- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon®, PVC, or metal slugs,
- One-quarter-inch nylon or polypropylene rope,
- Electric water level indicator,
- Pressure transducer/sensor,
- Field logbook/forms,
- Automatic data recording instrument (such as the Hermit® Environmental Data
- Logger, In-Situ, Inc. Model SE1000B or equal).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after water level measurements show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development or extended pumping, etc., may lead to inaccurate results. It is up to the field hydrogeologist to determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other down-hole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.2.2.2.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe the falling head test procedures.

1. Decontaminate all downhole equipment prior to initiating the test.

2. Open the well. Where wells are located within the 100-year flood plain and equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Prepare the Aquifer Test Data Form (Figure 3.7) with entries for:

    - Borehole/well number,
    - Project number,
    - Project name,
    - Aquifer testing team,

AQUIFER SLUG TEST DATA SHEET

Location__________ Client__________ Well No.__________

Job No. __________ Field Scientist__________ Date__________

Water Level__________ Total Well Depth__________

Measuring Datum__________ Elevation of Datum__________

Weather__________ Temp__________

Comments__________

Beginning Time	Ending Time	Initial Head Reading	Ending Head Reading	Test Type (Rise/Fall)	File Name	Comments

m:\forms\slug.doc 4/28/94

FIGURE 3.7

AQUIFER SLUG TEST DATA FORM

Intrinsic Remediation EE/CA
Former AGE Fuel Facility
Seymour Johnson AFB, NC

PARSONS ENGINEERING SCIENCE, INC.
Cary, North Carolina

DATA\950DWG\950009.DWG / 1=1 / 3-15-95 / tlp

- Climatic data,
- Ground surface elevation,
- Top of well casing elevation,
- Identification of measuring equipment being used,
- Page number,
- Static water level,
- Date, and
- Time intervals (0, 1, 3, 5, 7, 9, 10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).

4. Measure the static water level in the well to the nearest 0.01 foot.

5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.

6. Lower the decontaminated slug into the well to just above the water level in the well.

7. Turn on the data logger and quickly lower the slug below the water table being careful not to disturb the pressure transducer. Follow the owners' manual for proper operation of the data logger.

8. Terminate data recording when the water level stabilizes in the well.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedures.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.

2. Initiate data recording and quickly withdraw the slug from the well. Follow the owners' manual for proper operation of the data logger.

3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ (Geraghty & Miller, Inc., 1991) and the method of Hvorslev (1951) for confined aquifers, or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. Based on a review of site hydrogeology at the former AGE fuel facility site (Section 2.1.2), unconfined conditions dominate the site and the Bouwer and Rice method will be used for most of the hydraulic conductivity testing.

SECTION 4

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of fuel hydrocarbons dissolved in groundwater at the former AGE fuel facility site. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed on the basis of regulatory action levels. If it is shown that intrinsic remediation of BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at this site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free-product recovery, groundwater pump-and-treat, enhanced biological treatment, bioventing, biosparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume reduction that should result from remedial actions

Upon completion of Bioplume II modeling and remedial option selection, a report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model developed for this site.

TABLE 4.1
INTRINSIC REMEDIATION EE/CA REPORT OUTLINE
SEYMOUR JOHNSON AFB, NORTH CAROLINA

INTRODUCTION
- Scope and Objectives
- Site Background

SITE CHARACTERIZATION ACTIVITIES
- Geoprobe, Sampling, and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA
- Surface Features
- Regional Geology and Hydrogeology
- Site Geology and Hydrogeology
- Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION
- Source Characterization
- Soil Chemistry
  - Residual-Phase Contamination
  - Total Organic Carbon
- Ground Water Chemistry
  - LNAPL Contamination
  - Dissolved Contamination
  - Ground Water Geochemistry
  - Expressed Assimilative Capacity

GROUND WATER MODEL
- Model Description
- Conceptual Model Design and Assumptions
- Initial Model Setup
- Model Calibration
- Sensitivity Analysis
- Model Results
- Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
- Remedial Alternative Evaluation Criteria
  - Long-Term Effectiveness
  - Implementability (Technical, Administrative)
  - Cost (Capital, Operating, Present Worth)
- Factors Influencing Alternatives Development
  - Program Objectives
  - Contaminant Properties
  - Site-Specific Conditions
- Brief Description of Remedial Alternatives
  - Intrinsic Remediation with Long-Term Monitoring
  - Other Alternatives
- Evaluation of Alternatives
- Recommended Remedial Approach

TABLE 4.1 (continued)
INTRINSIC REMEDIATION EE/CA REPORT OUTLINE
SEYMOUR JOHNSON AFB, NORTH CAROLINA

LONG-TERM MONITORING PLAN
- Overview
- Monitoring Networks
- Ground Water Sampling

CONCLUSIONS AND RECOMMENDATIONS
- How does the recommended technology offer adequate protection for less cost.

APPENDICES: Supporting Data and Documentation
- Site-Specific Bioplume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of the water level probe and cable; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Groundwater samples from the Geoprobe® system should provide sufficient volume for some duplicate analysis. Refer to Appendix B for further details on volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected. Because disposable bailers may be used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

TABLE 5.1
QA/QC SAMPLING PROGRAM
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	10% of Samples per Matrix [a/]	VOCs, TPH
Rinseate Blanks	10% of Ground Water Samples [a/]	VOCs
Field Blanks	5% of Ground Water Samples [a/]	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

[a/] Rounded to the next highest whole number.

A field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions and conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory and will be transported inside one of the coolers containing samples. This sample will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

Laboratory control samples (LCSs) and laboratory method blanks (LMBs) will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

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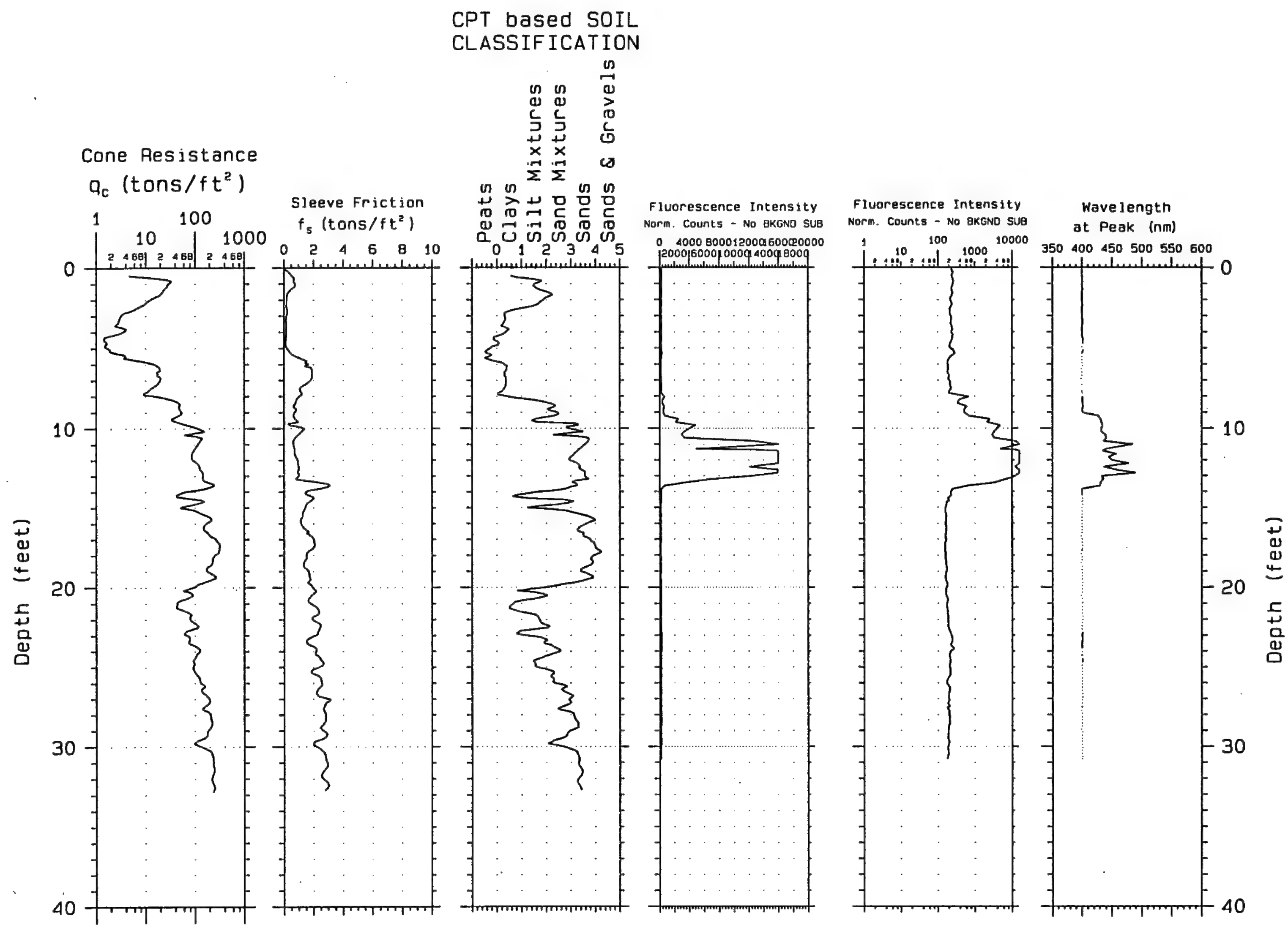
APPENDIX A

CPT/LIF DATA



Project; Semour Johnson AFB <NEW>

Probe Depth; 32.94

Laser induced fluorescence of POL via fiber optics

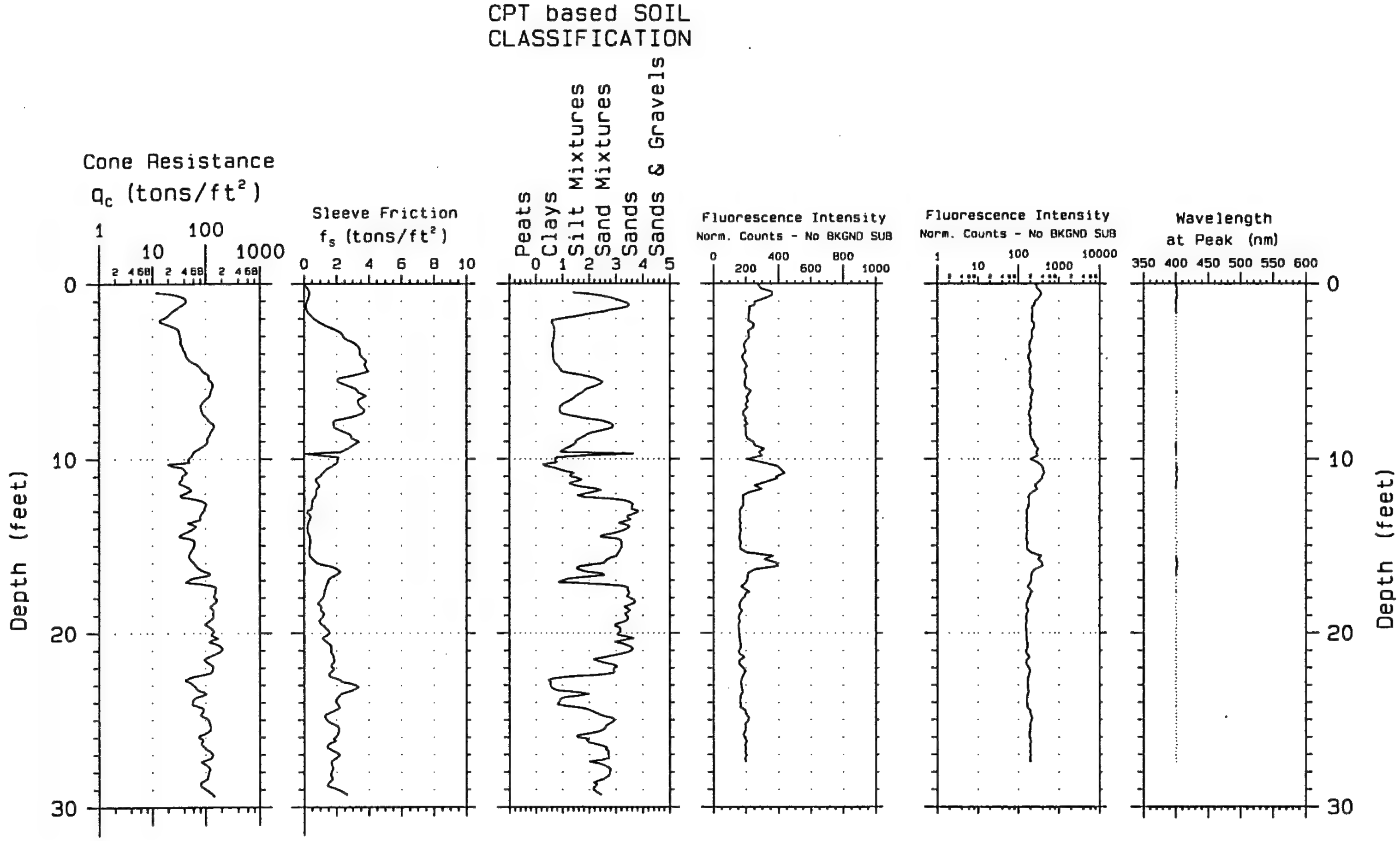
U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

CPT; 2SEMF1

Probing date; 01-19-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Project; Seymour Johnson AFB <NEW>

Probe Depth; 29.62

SCAPS

Site Characterization and Analysis Penetrometer System

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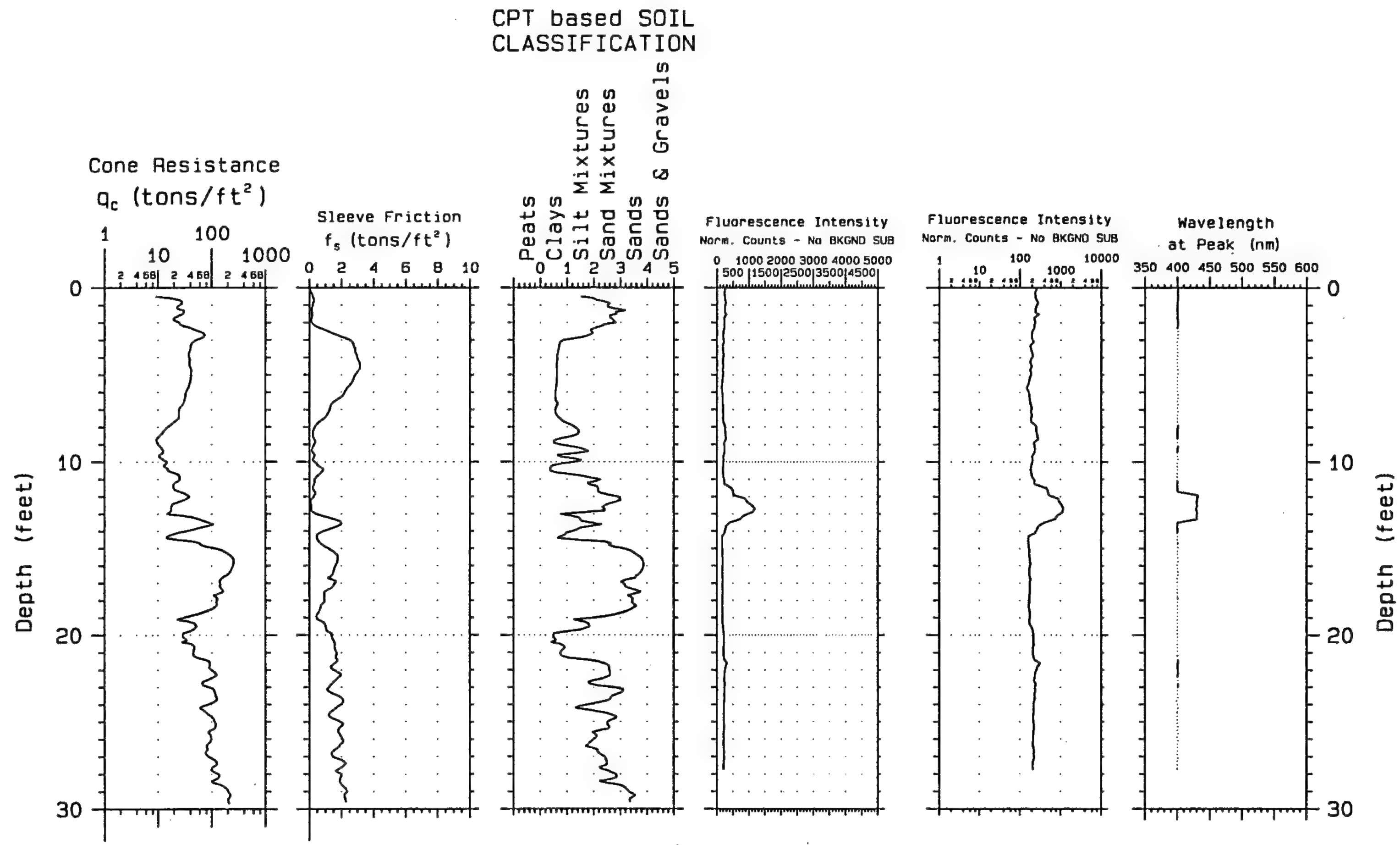
Probing date; 01-20-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

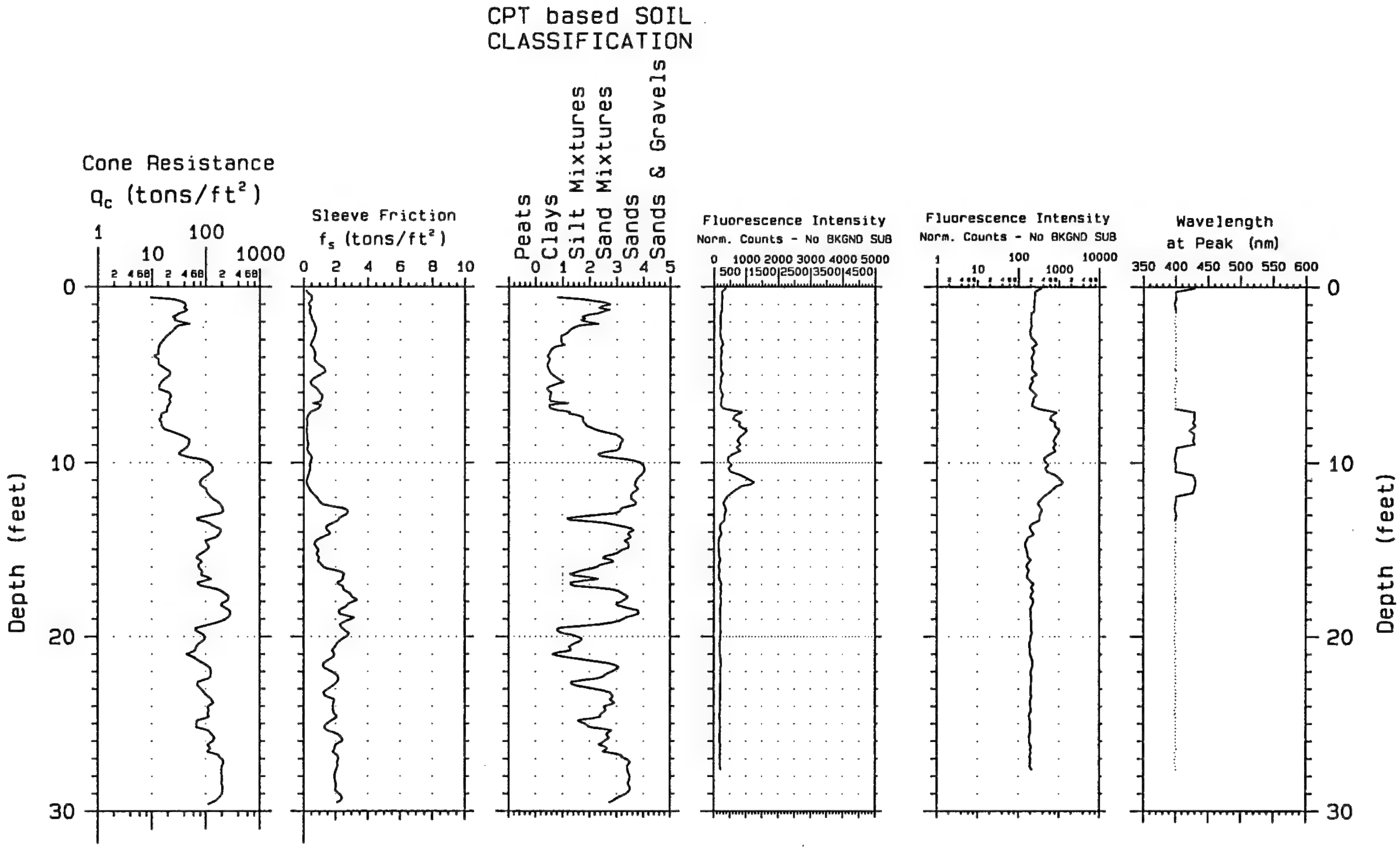
Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

Probe Depth; 29.89

CPT; 4SEMF3

Probing date; 01-20-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

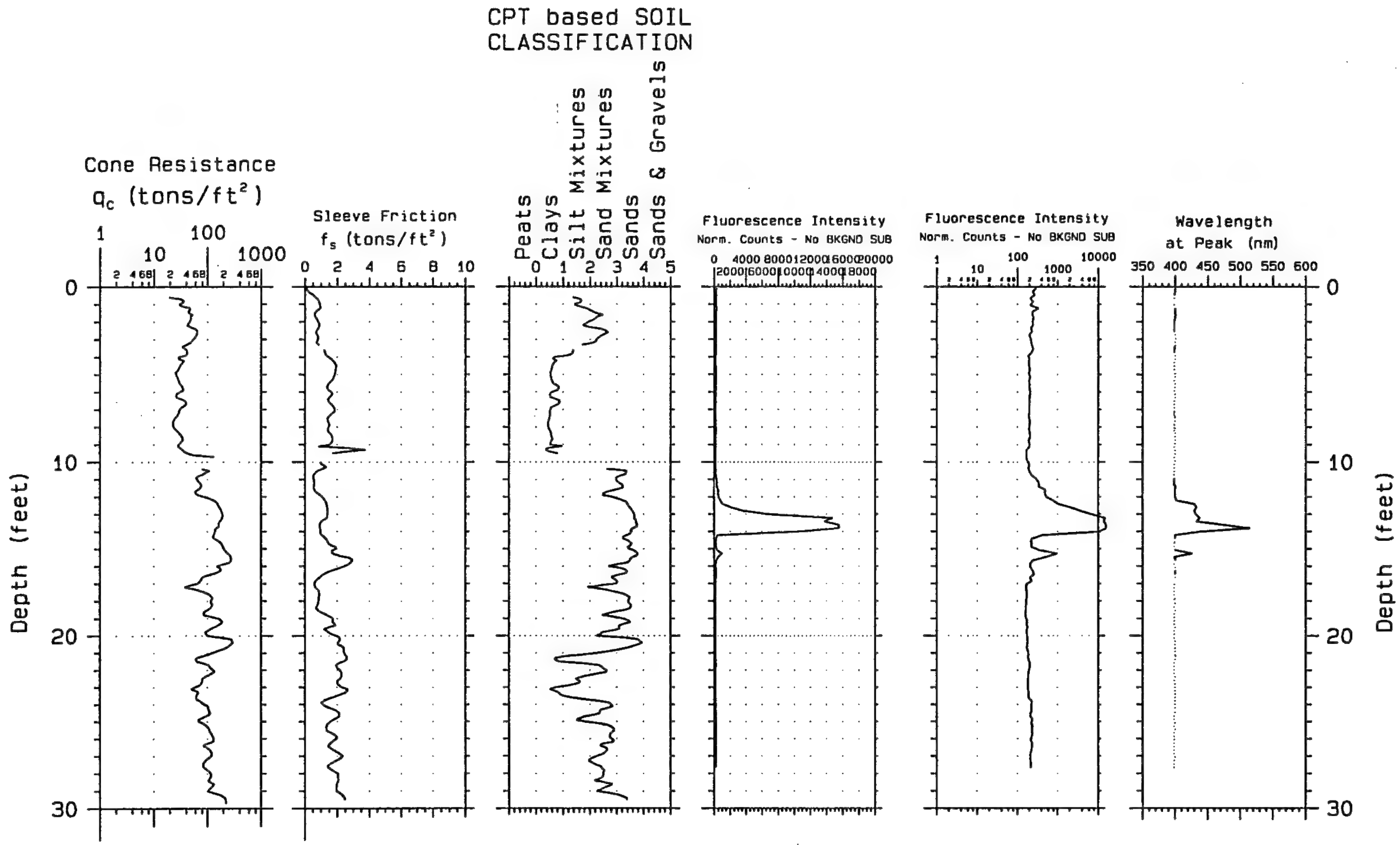
Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

Probe Depth; 29.80

CPT; 5SEMF4

Probing date; 01-20-1995



Project; Seymour Johnson AFB

Probe Depth; 29.86

Laser induced fluorescence of POL via fiber optics

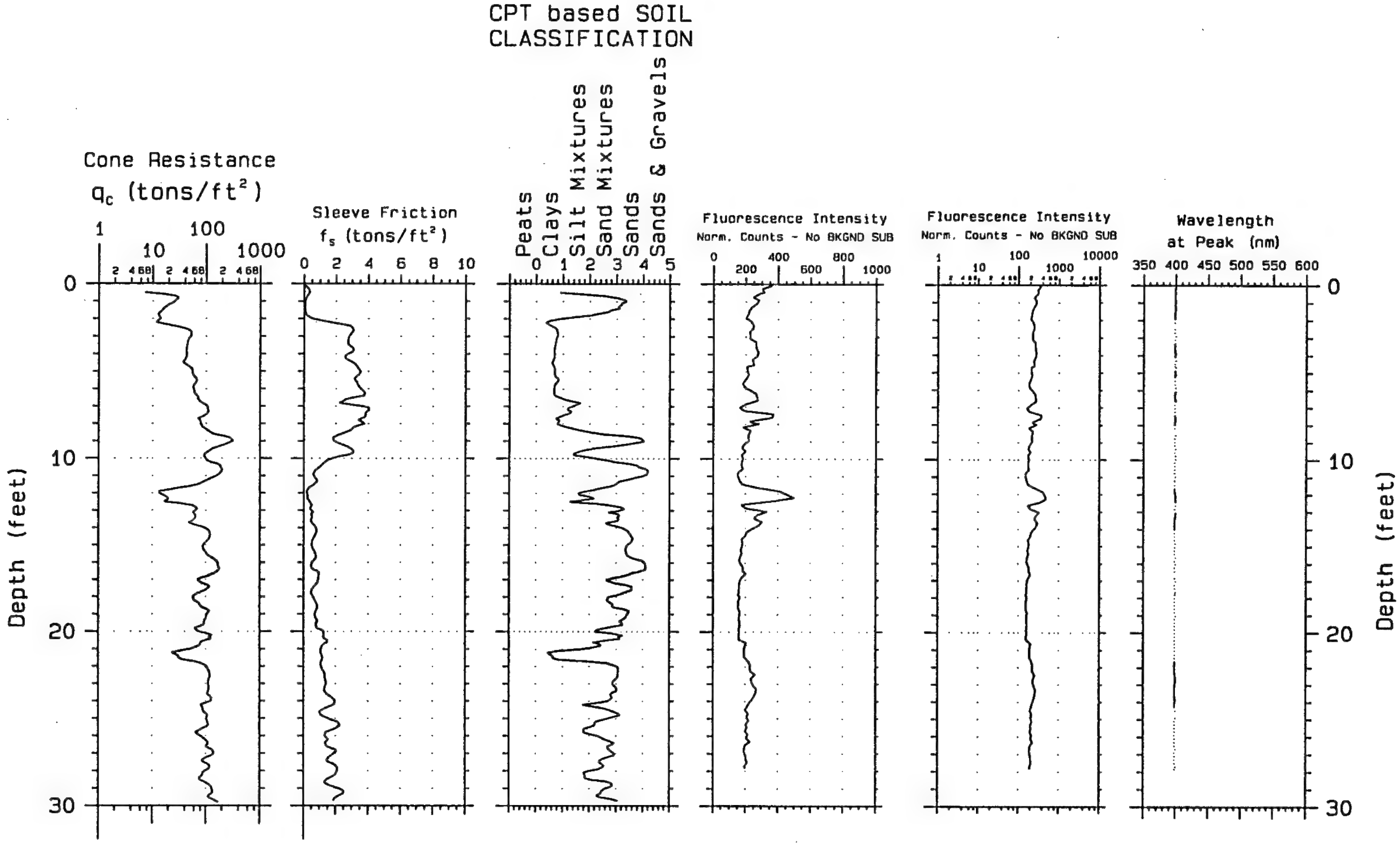
U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

CPT; 6SEMF5

Probing date; 01-20-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Probing date; 01-20-1995

SCAPS Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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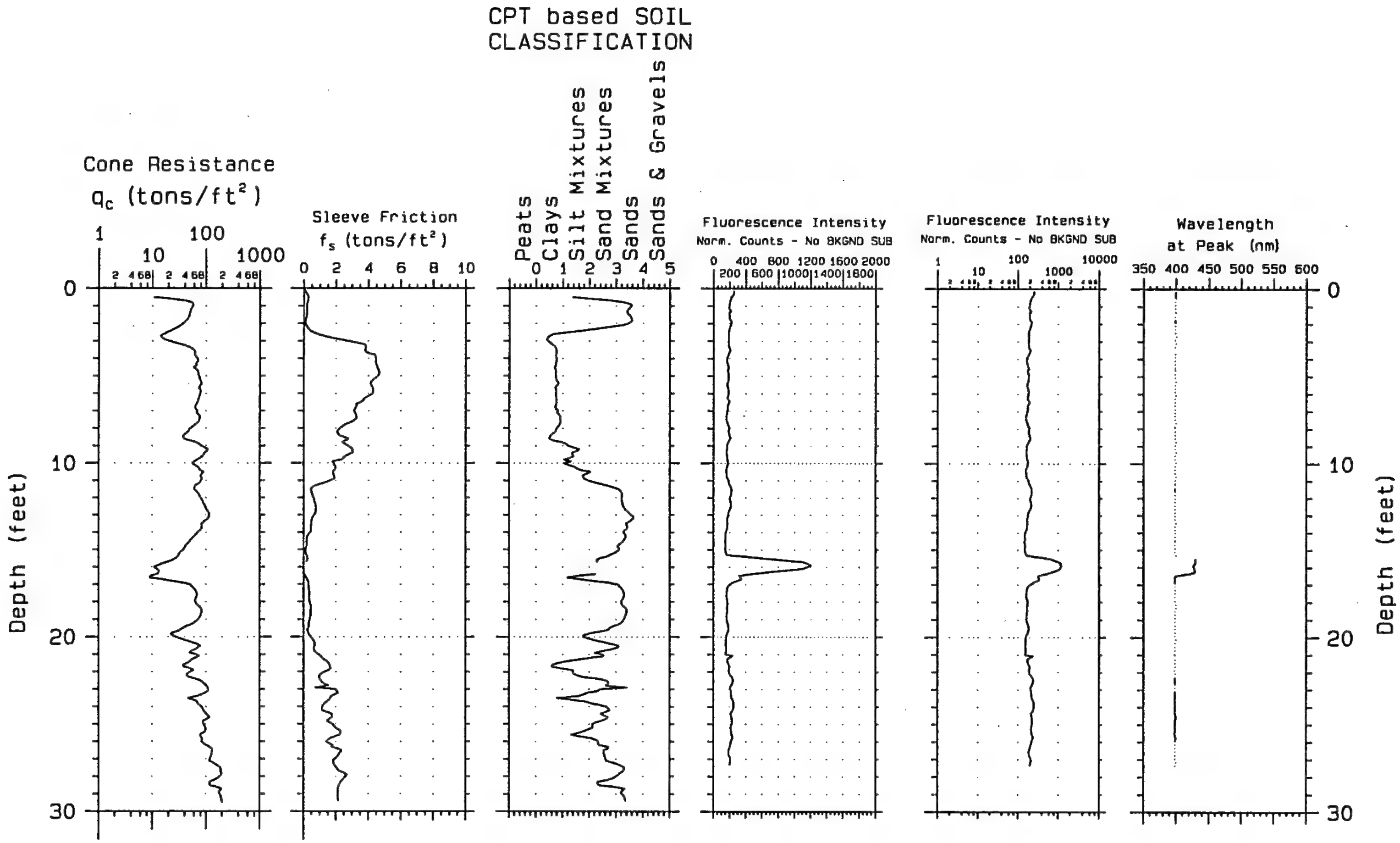
CPT; 7SEMF6



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Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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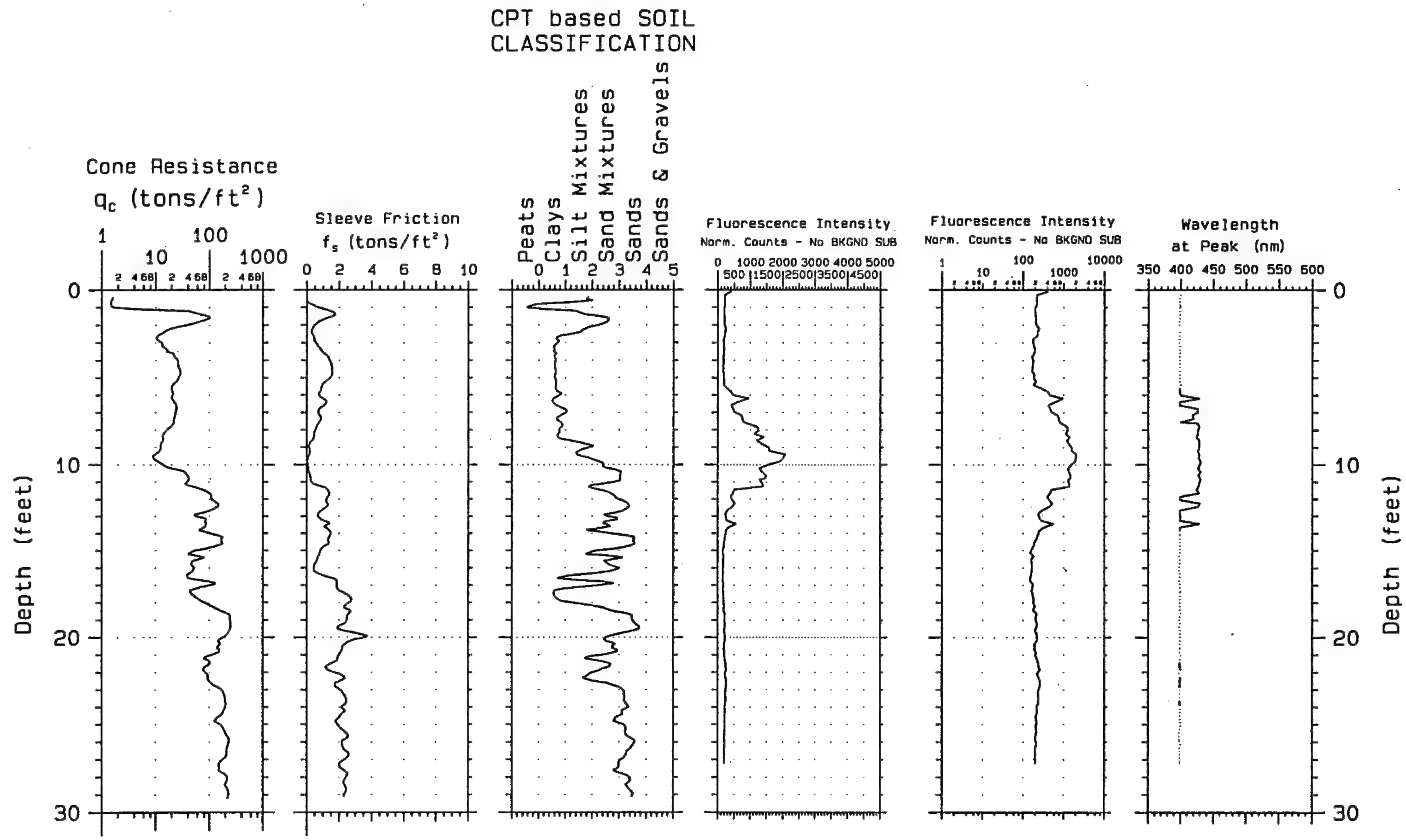
CPT; 8SEMF7



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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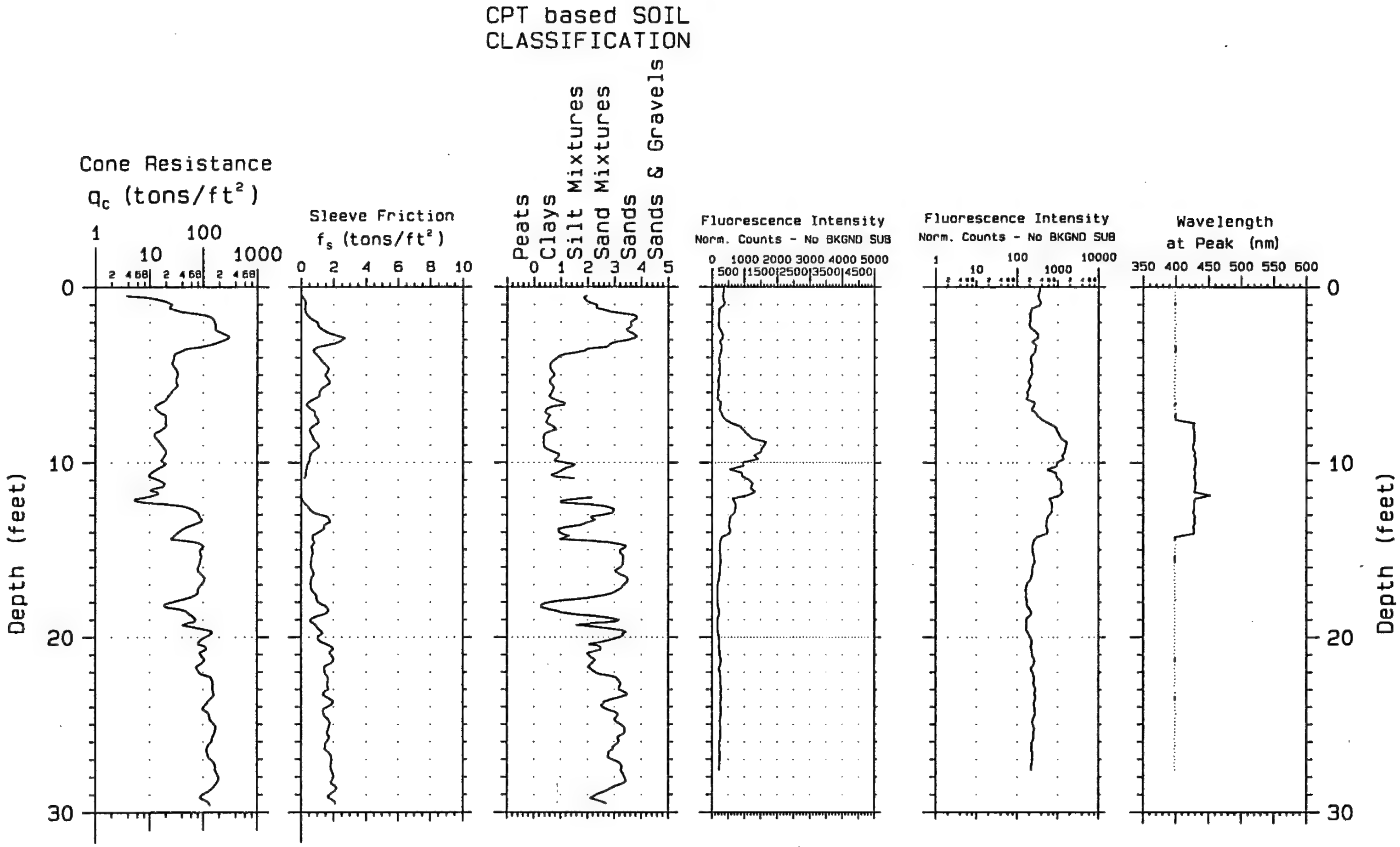
CPT; 10SEMF8

Probing date; 01-20-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

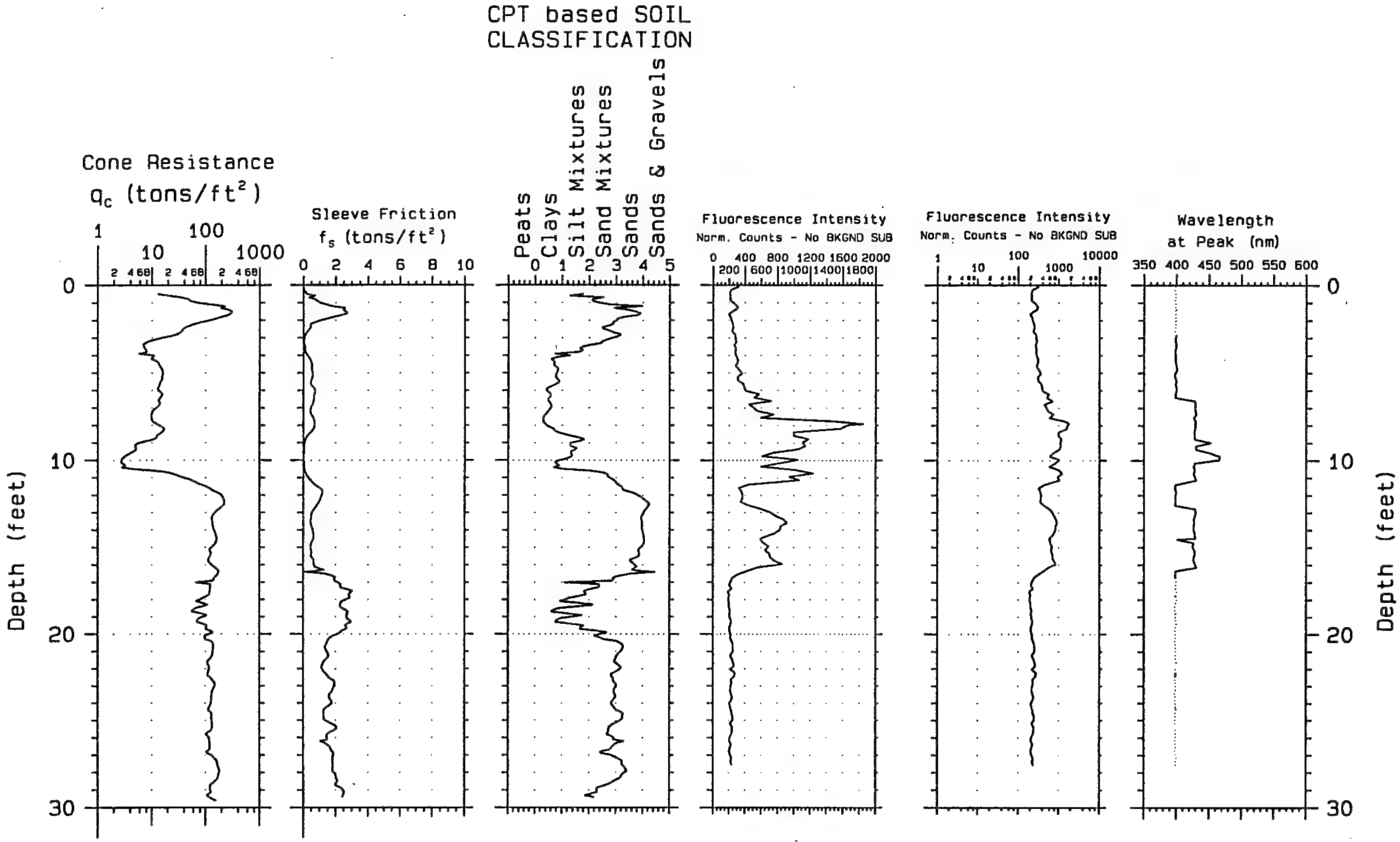
SCAPS Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

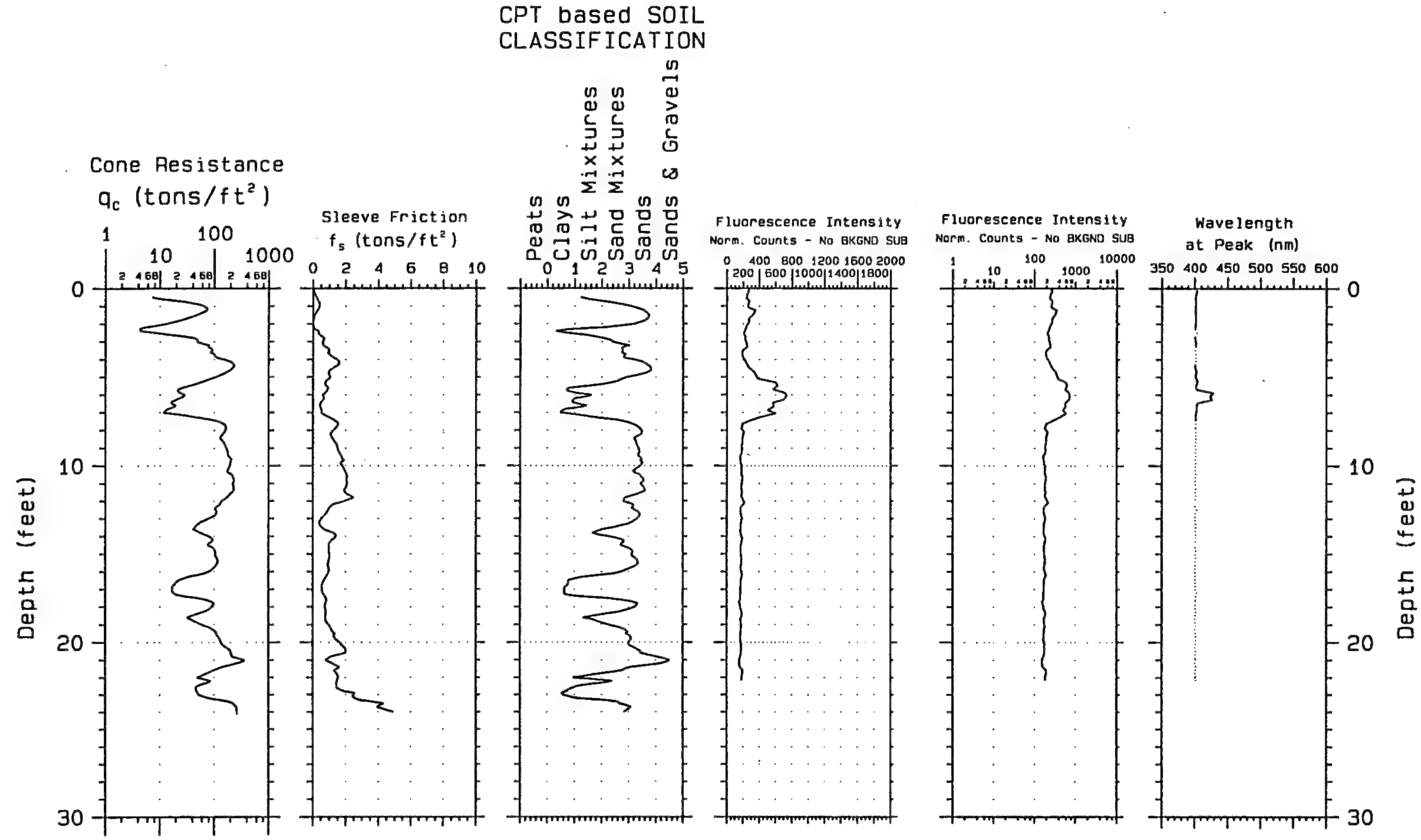
Probe Depth; 29.76

CPT; 11SEMF9

Probing date: 01-20-1995



Laser induced fluorescence of POL via fiber optics	Project; Seymour Johnson AFB
U.S.Army Engineer District Kansas City Geotechnical Branch	Probe Depth; 29.76
Probing date; 01-20-1995	**SCAPS** Site Characterization and Analysis Penetrometer System **CPT; 12SEMF10**



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Project; Seymour Johnson AFB

Probe Depth; 24.28

SCAPS

Site Characterization and Analysis Penetrometer System

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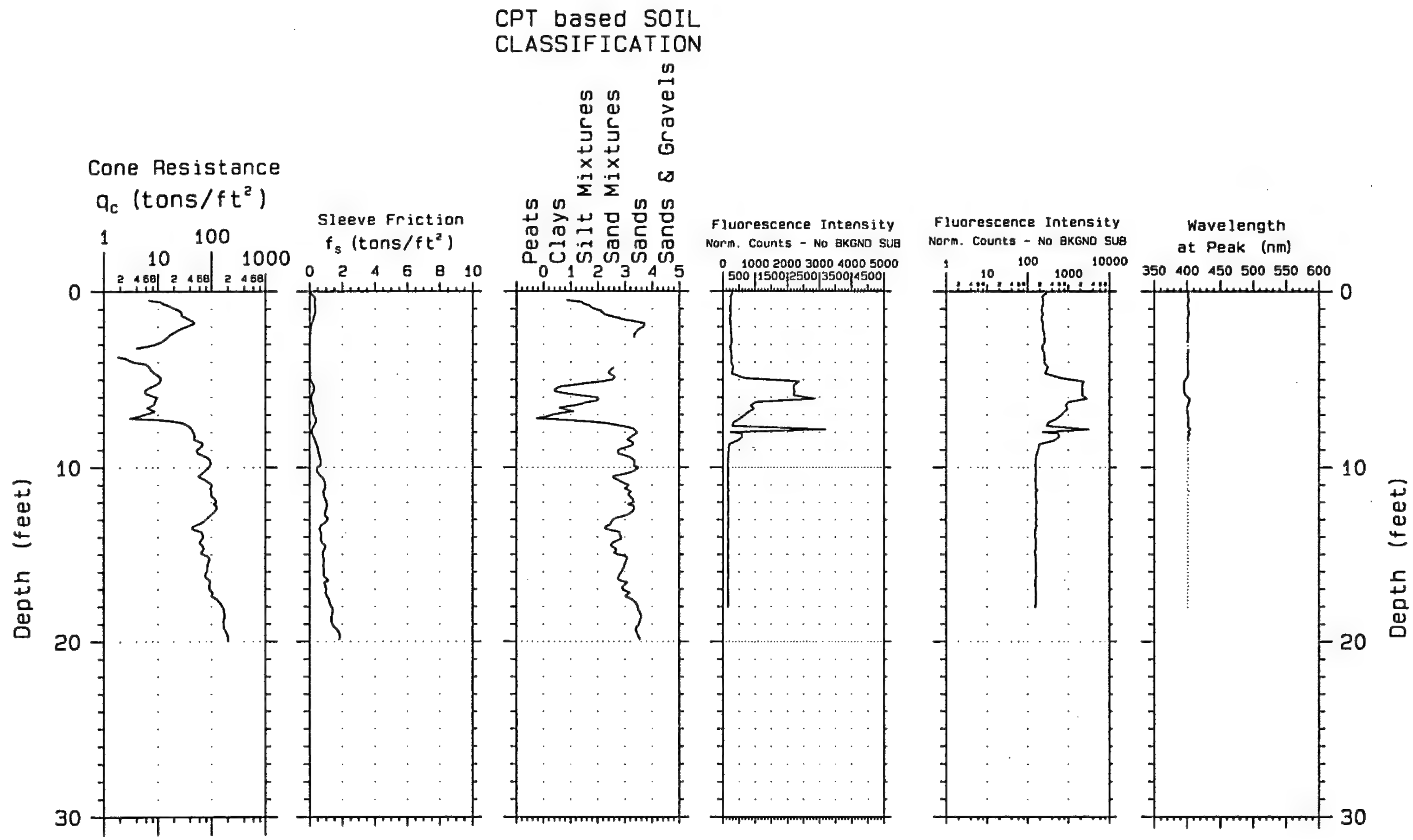
CPT; 20SEMF13



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Probing date; 01-21-1995

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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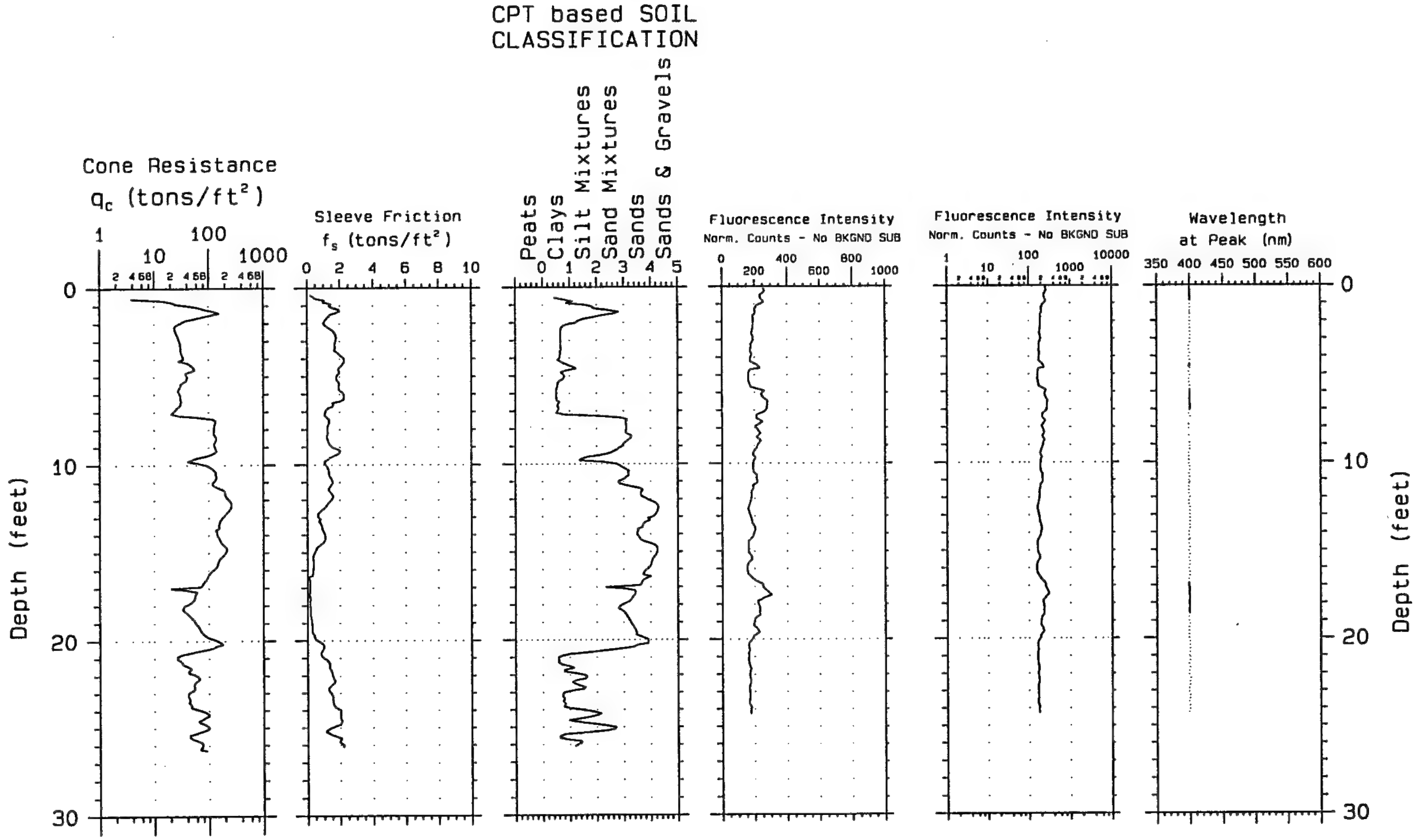


Project; Seymour Johnson AFB

Probe Depth; 26.42

Laser induced fluorescence of POL via fiber optics

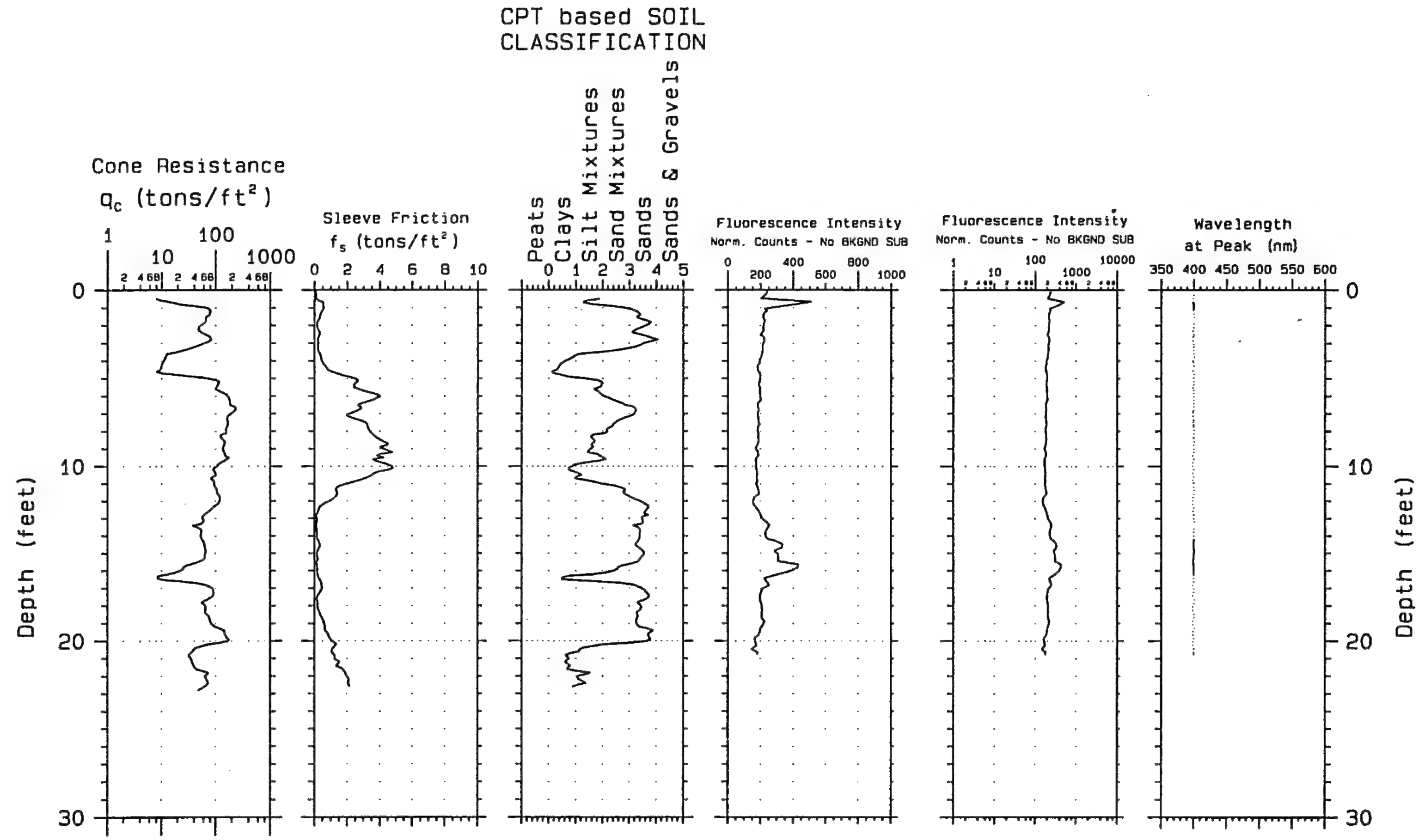
U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

CPT; 24SEMF15

Probing date; 01-21-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

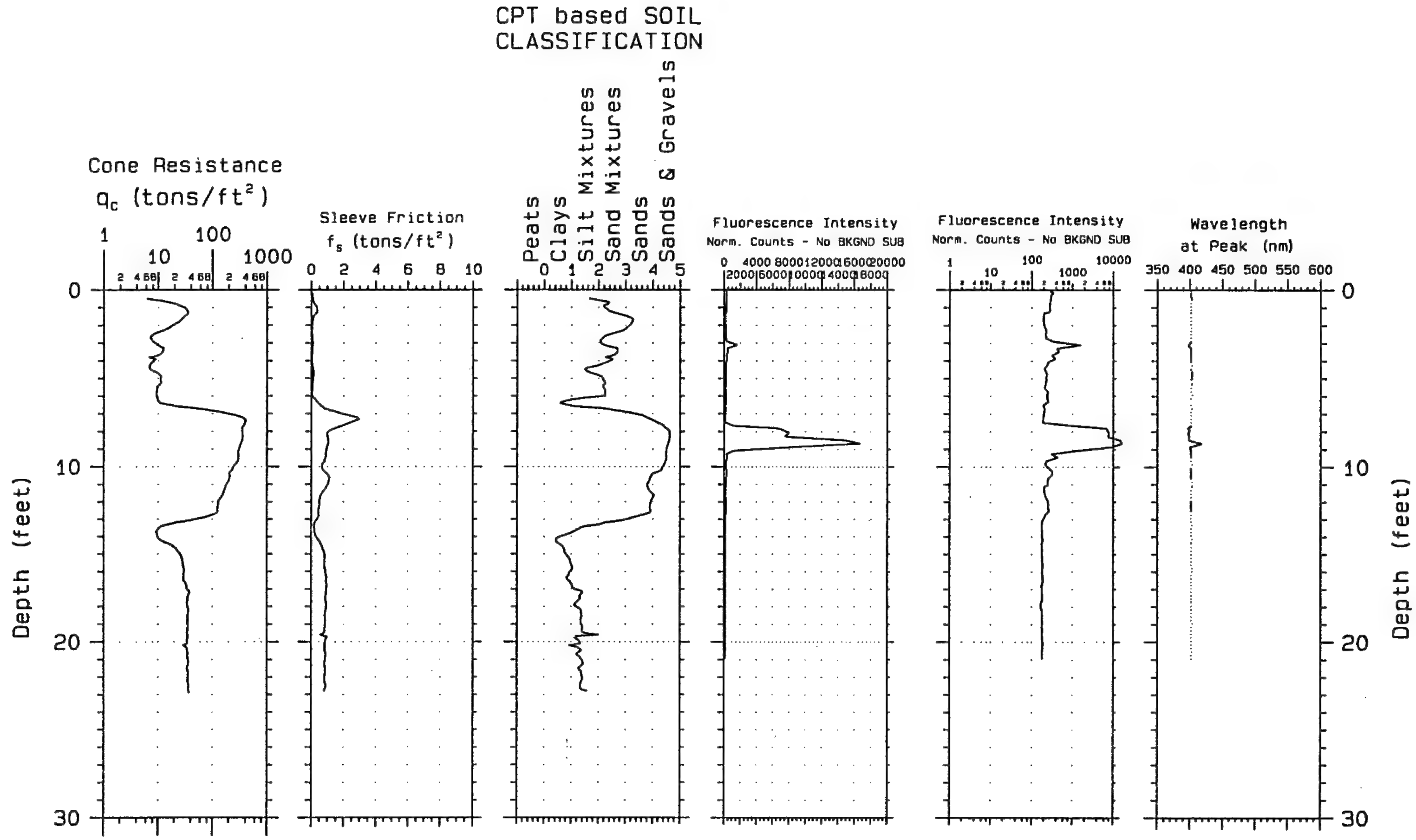
Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

Probe Depth; 22.91

CPT; 25SEMF16

Probing date; 01-21-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Probing date: 01-23-1995

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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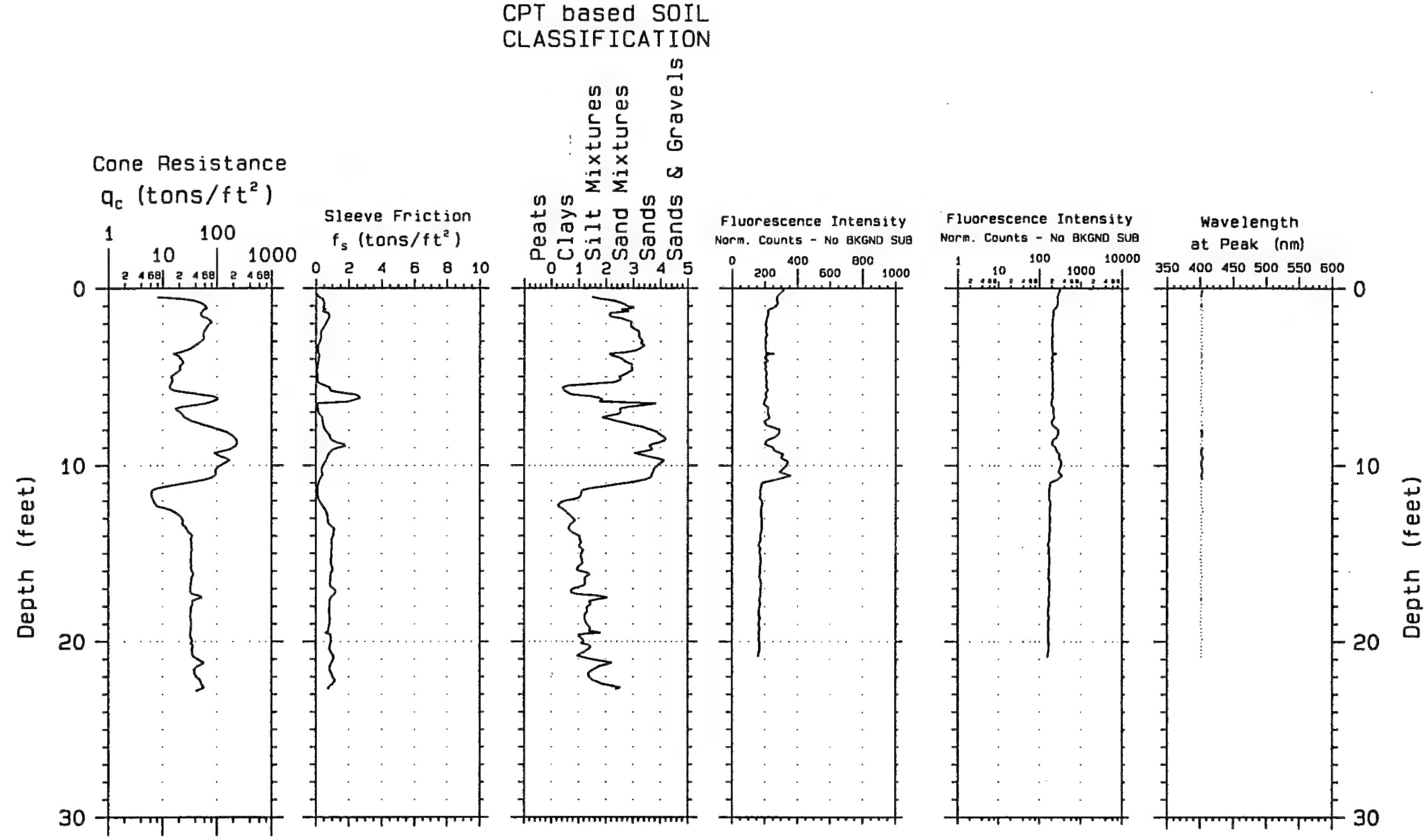

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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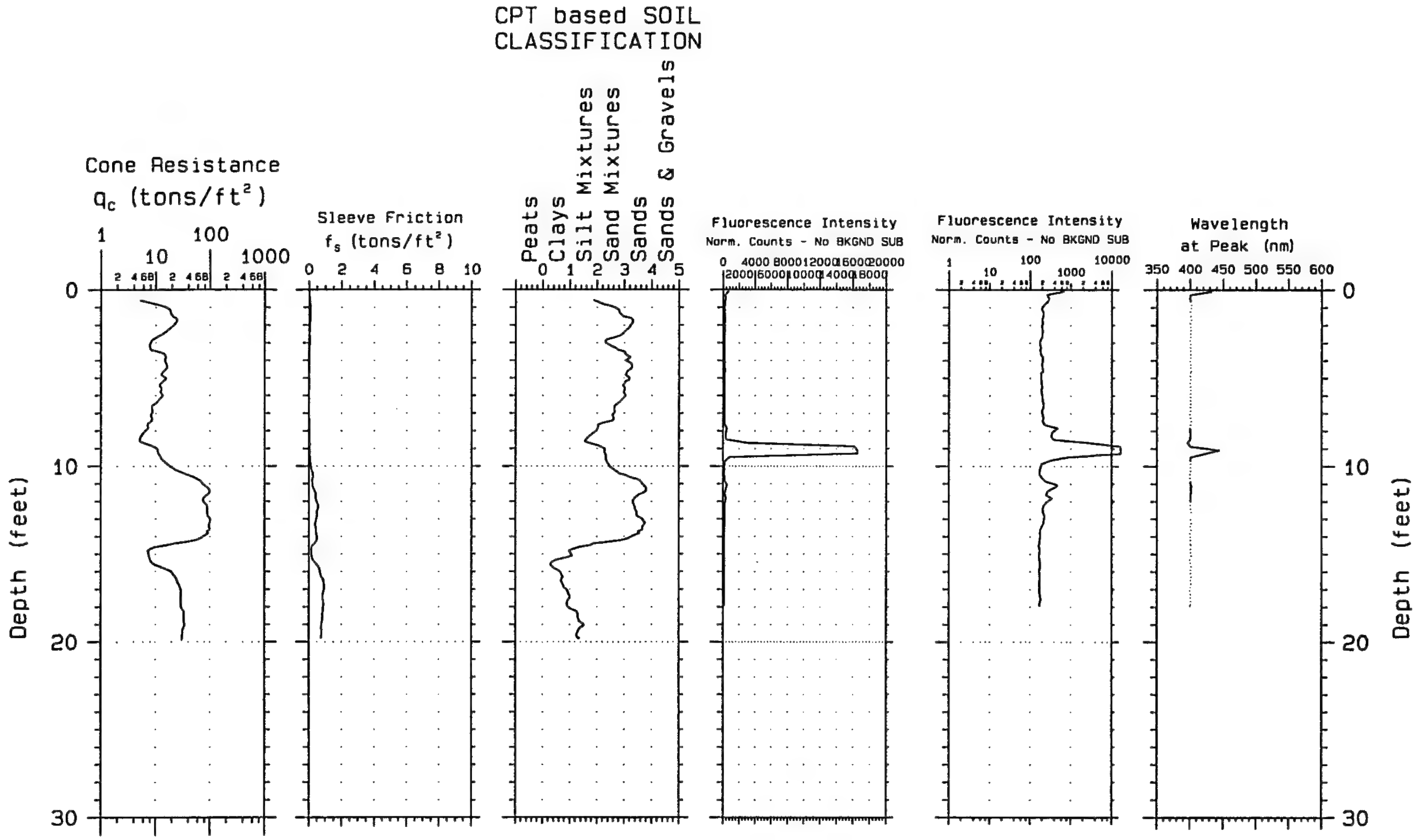
CPT; 28SEMF18

Probing date; 01-23-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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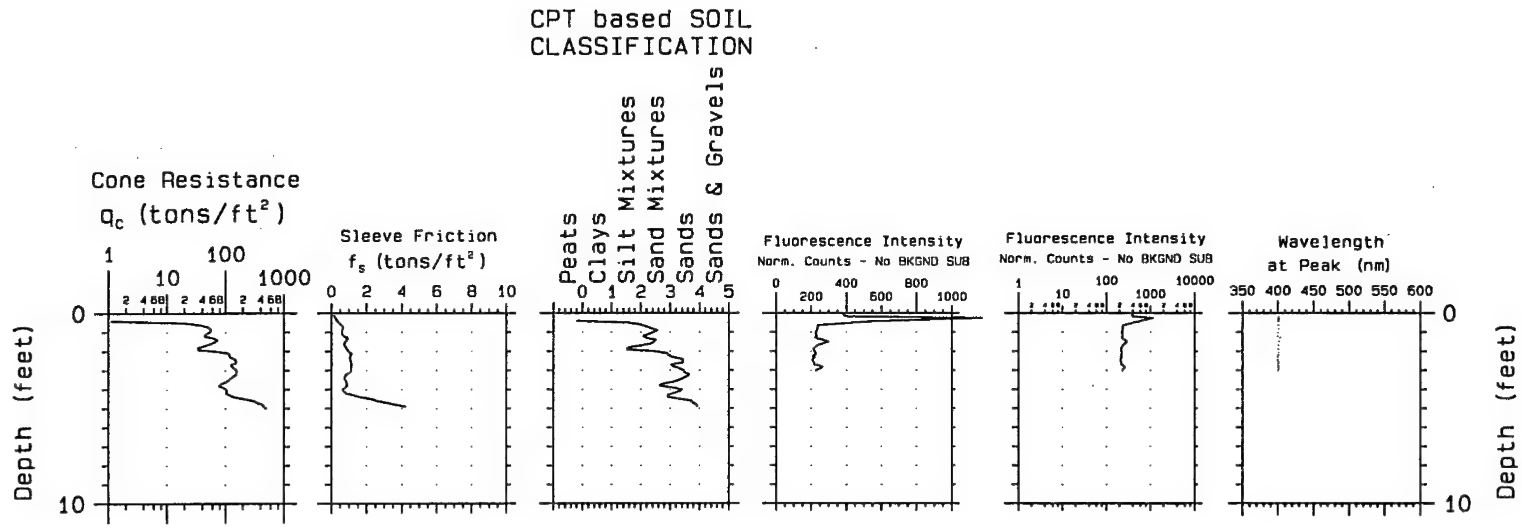
CPT; 30SEMF20

Probing date: 01-23-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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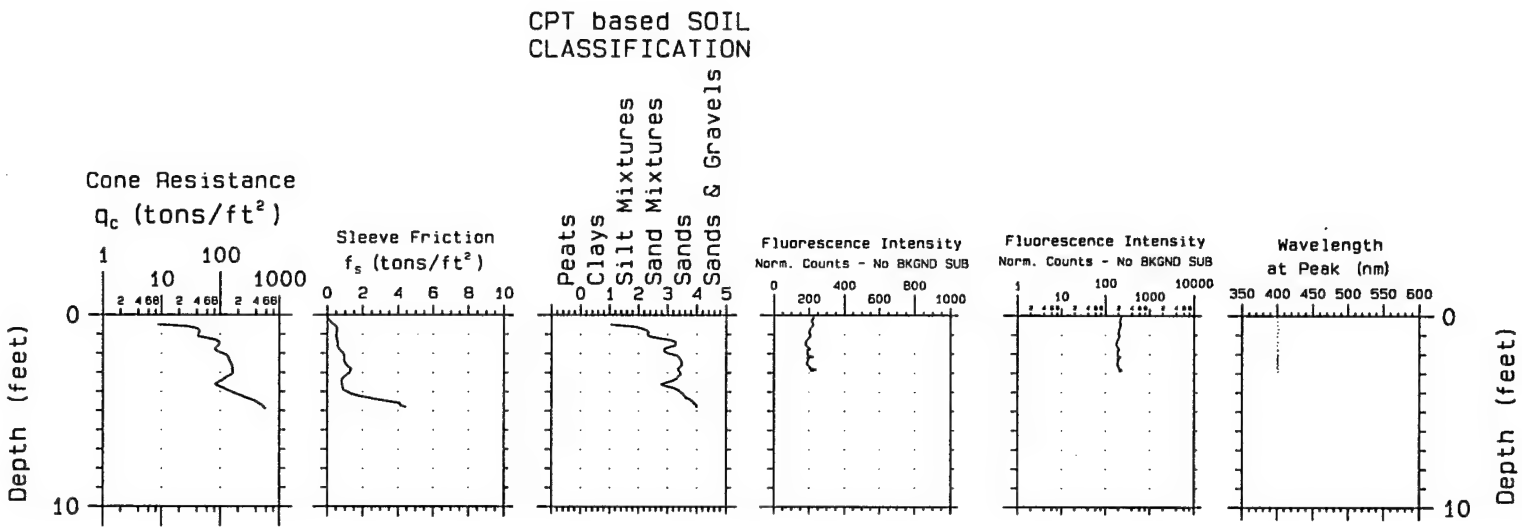
Probing date; 01-23-1995



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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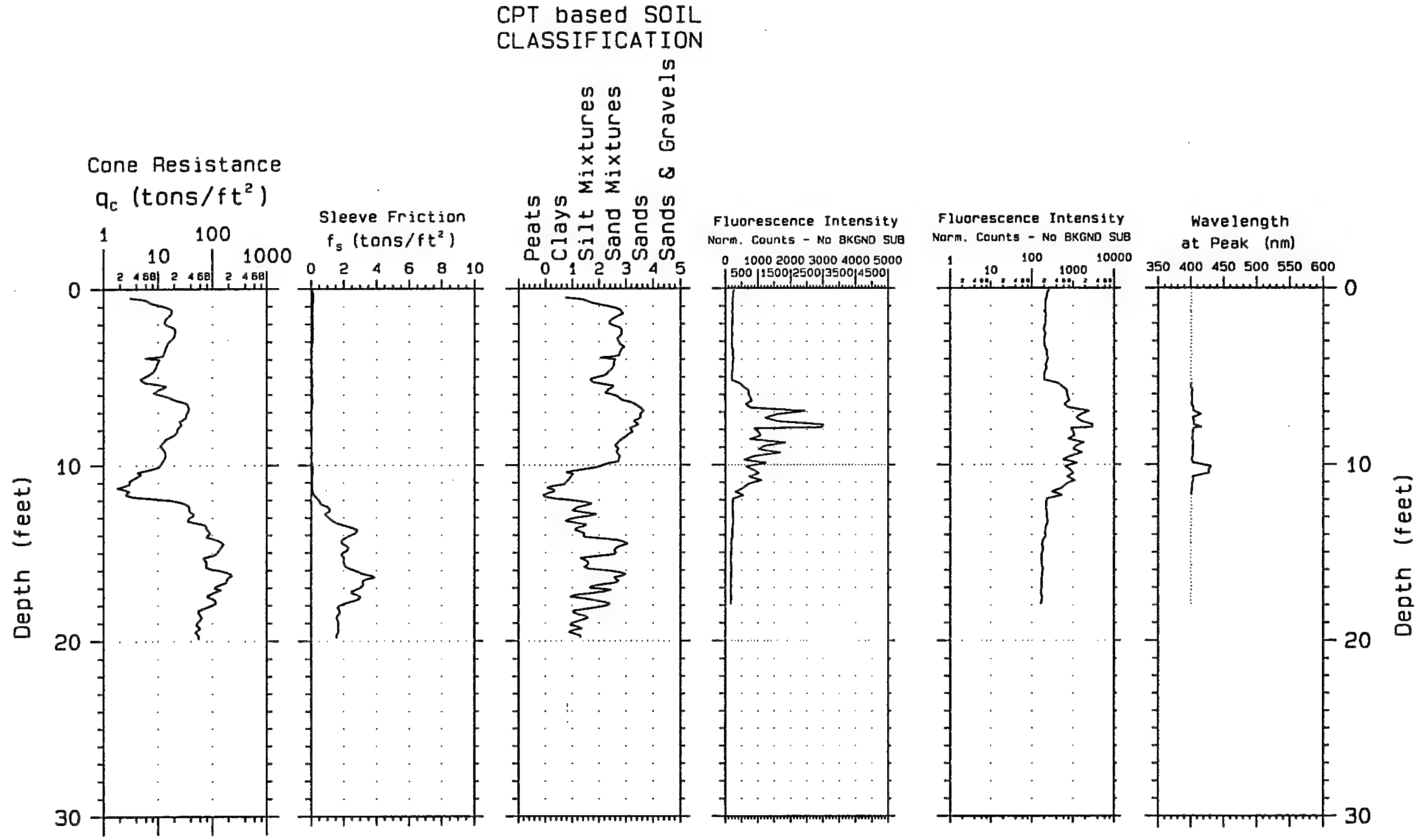

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Probing date; 01-23-1995

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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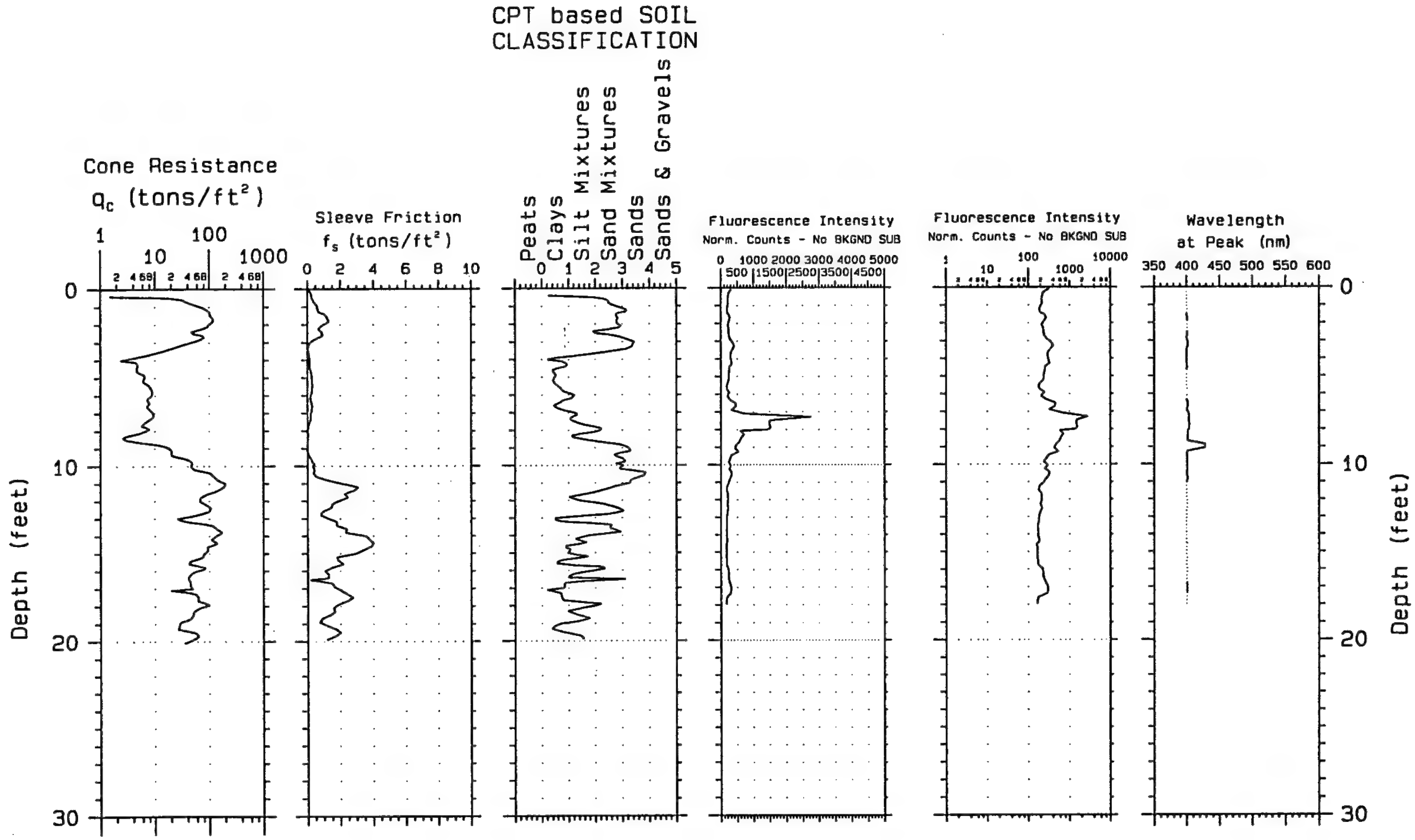

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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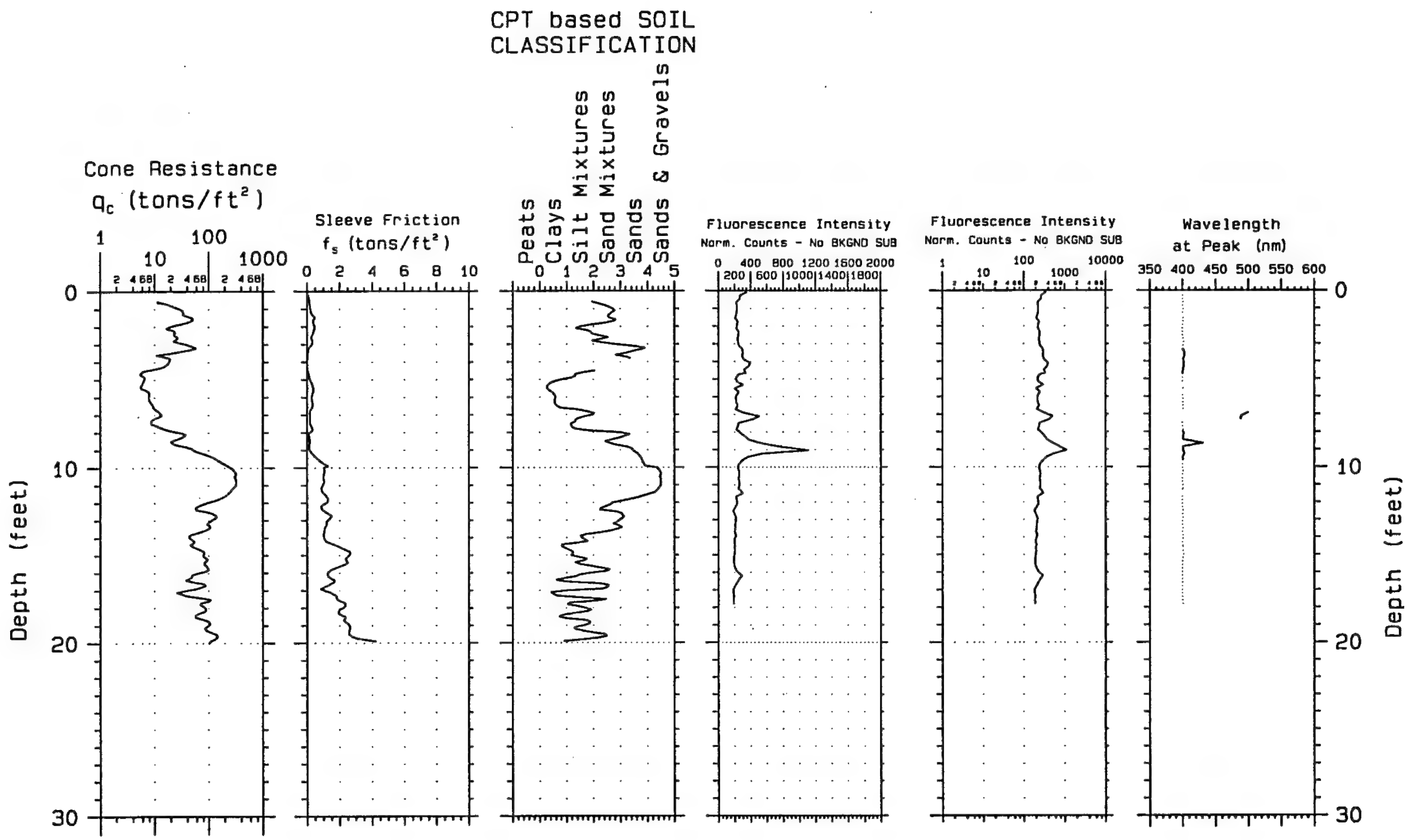

Probing date; 01-23-1995

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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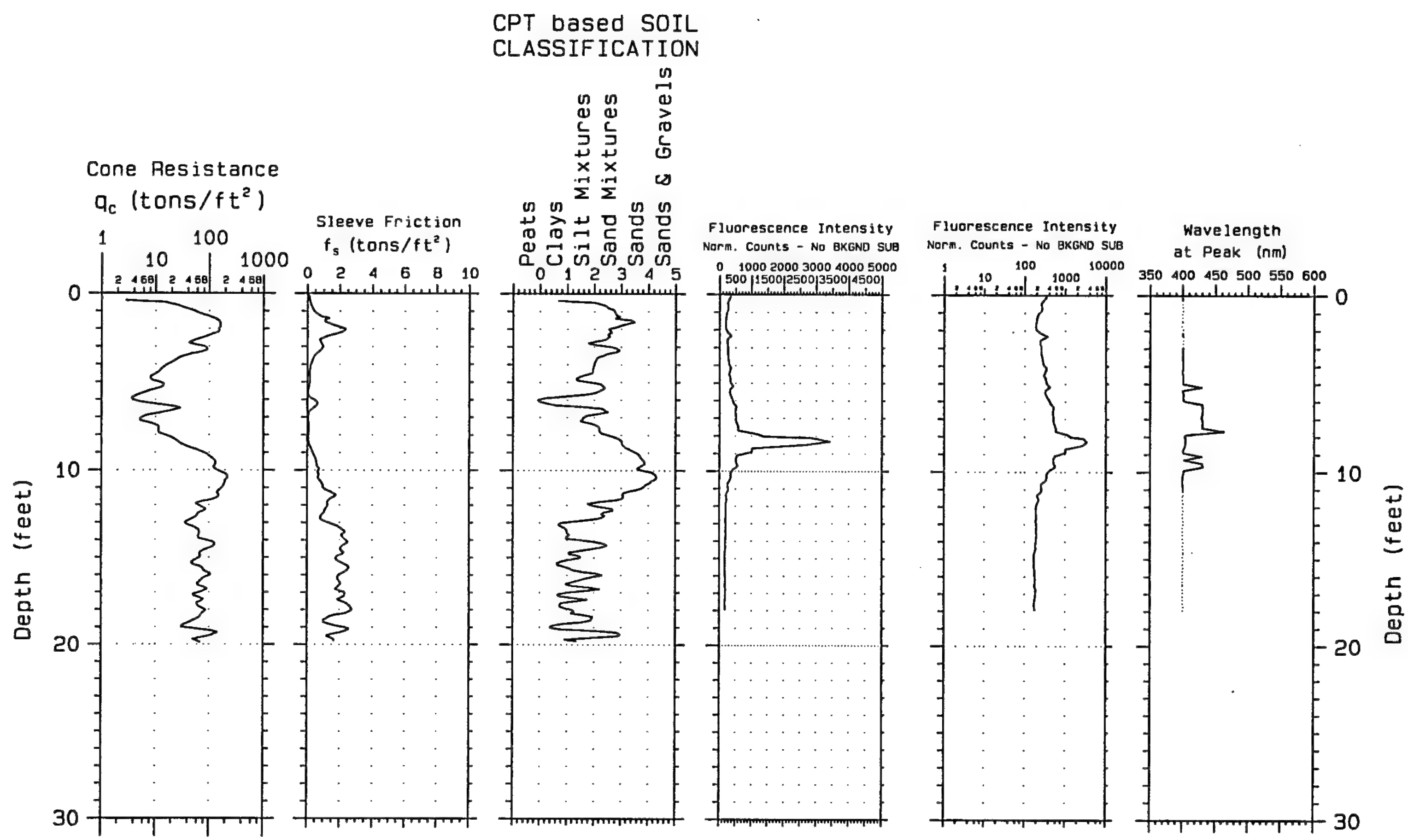

Probing date; 01-23-1995

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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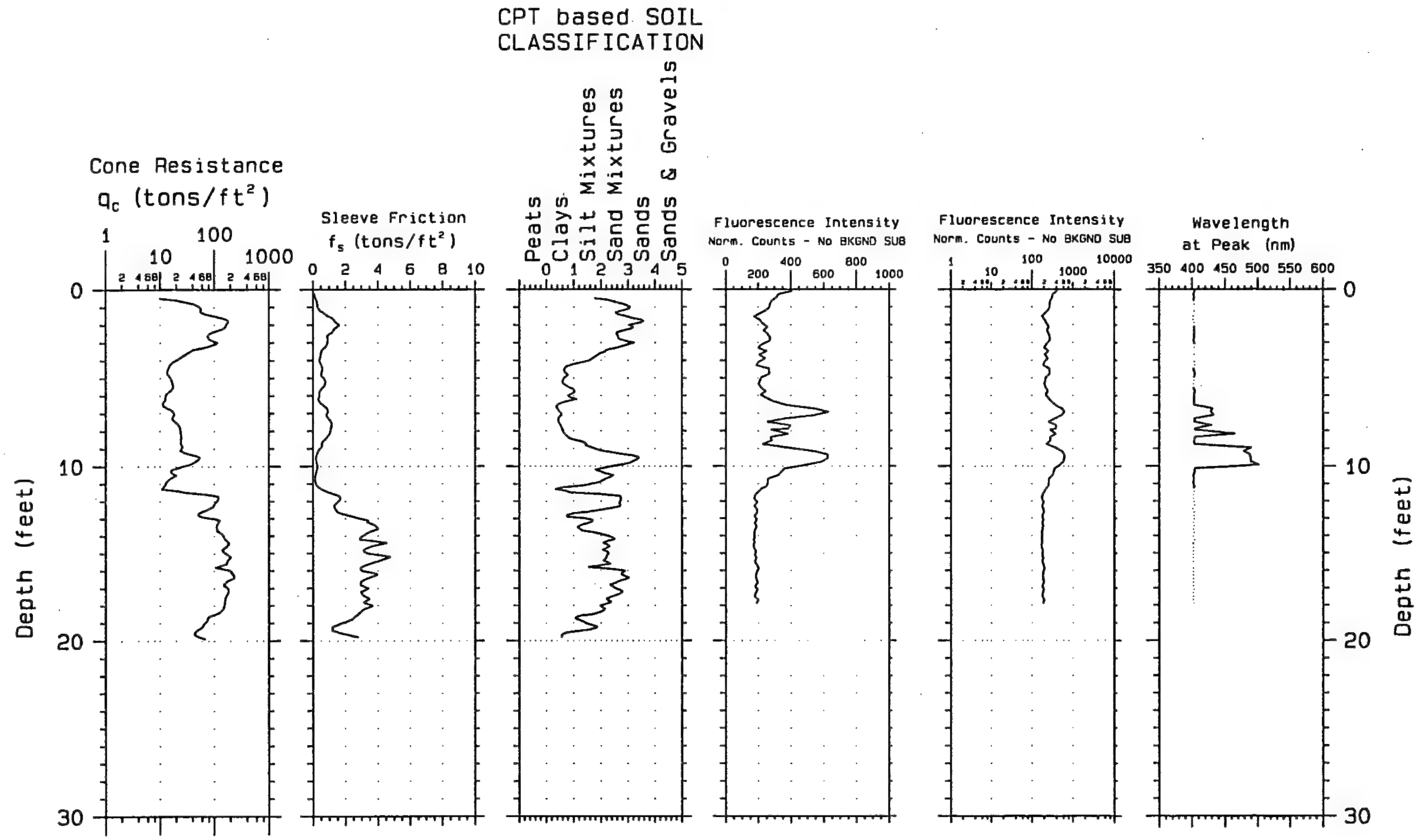

Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

Probing date; 01-24-1995

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

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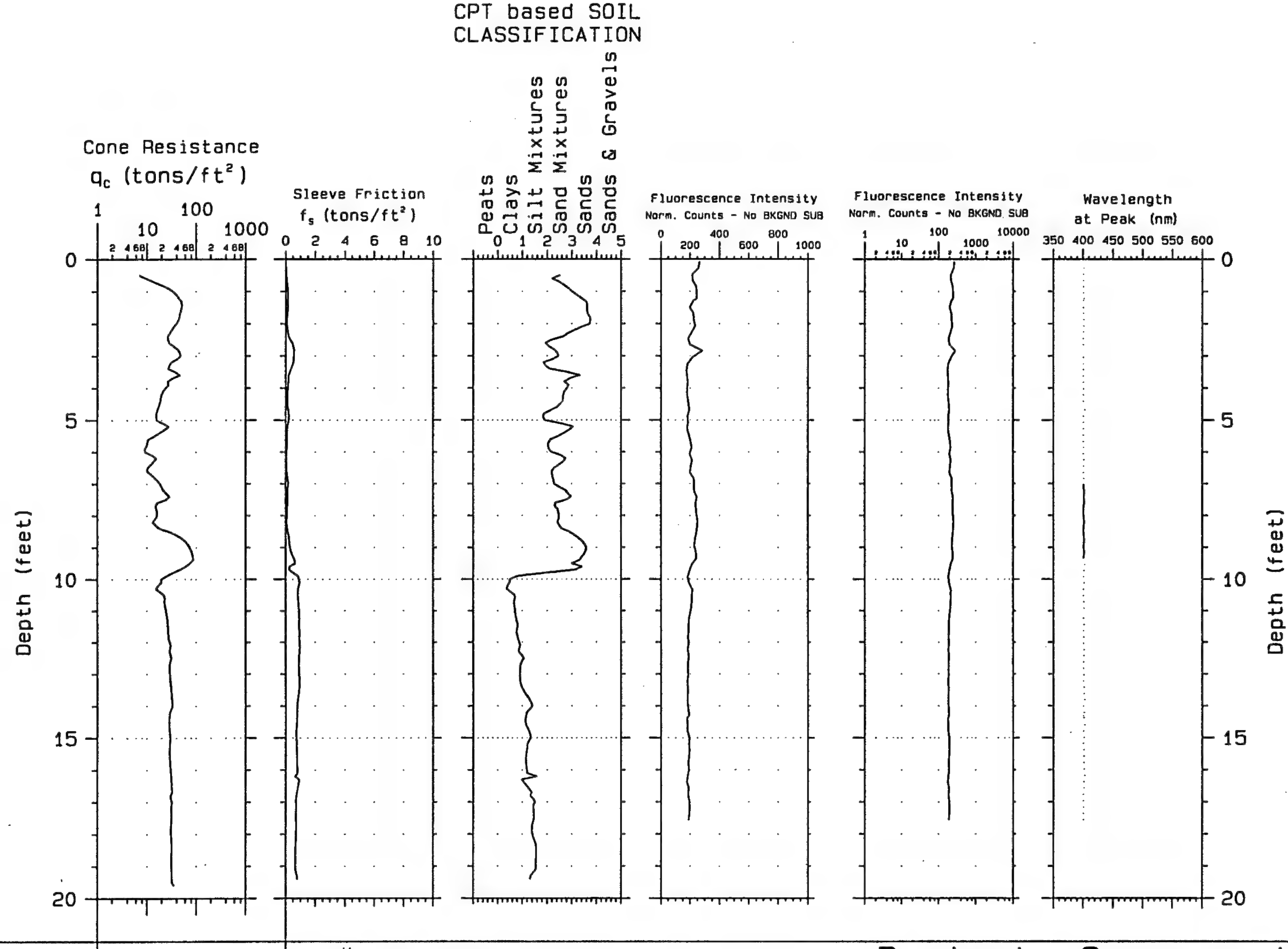
CPT; 38SEMF27



Laser induced fluorescence of POL via fiber optics

U.S.Army Engineer District Kansas City Geotechnical Branch

SCAPS

Site Characterization and Analysis Penetrometer System

Project; Seymour Johnson AFB

Probe Depth; 19.73

CPT; 39SEMF28

Probing date: 01-24-1995

APPENDIX B

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR GROUNDWATER SAMPLES

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/ mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Ferrous (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen *in situ*	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Water	Methane; carbon dioxide	RSKSOP-175 modified to analyze water samples for methane and carbon dioxide by headspace sampling with dual thermal conductivity and flame ionization detection (also, see reference in note 10)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps; cool to 4°C	Fixed-base

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the bio-transformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons–collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons–collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

TABLE B.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
SEYMOUR JOHNSON AIR FORCE BASE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field

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NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure.*
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.